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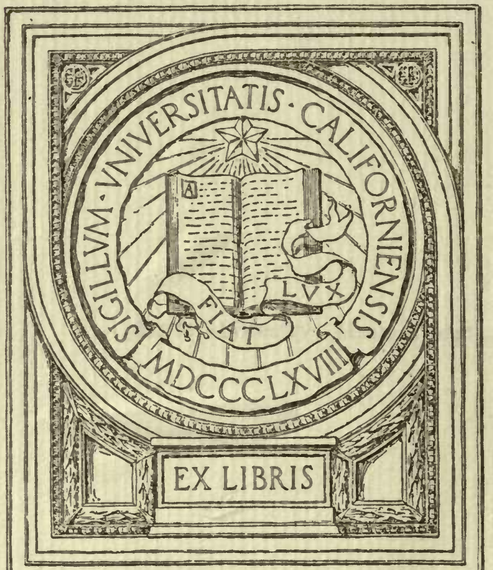

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KANSAS

Vol. II.

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Treatment and Utilization of Flood-damaged Lands. Agri. Exp. Sta., Kan. St. Agri. Col. Bulletin 121. Jan. 1904.

Disposal of Dairy and Farm Sewage, and Water-supply. By Oscar Erf. Agri. Exp. Sta. K.S.A.C. Bulletin 143. February, 1907.

The Pocket Gopher. Agri. Exp. Sta. K.S.A.C. Bulletin 152, Theo H. Scheffer. February, 1908.

The Influence of Deptj of Cultivation upon Soil Bacteria and Their Activities. By Walter E. King Charles J.T. Doryland. Exp. Sta. K.S.A.C. Bulletin 161. August 12, 1909.

The Common Mole. By Theo. H. Scheffer. Exp. Sta. K.S.A.C. Bulletin 168. August 1, 1910.

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JANUARY, 1917. CIRCULAR NO. 58

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THE WOODLOT

BY

CHAS A. SCOTT.

(From the Twentieth Biennial Report of the Kansas State Board of Agriculture.)

THE CARE of the woodlot is an important item in farm management that has received but little attention in this state. Every acre of natural or planted timber growing on Kansas farms should be a source of income and profit to the farm. The products from the woodlot are sawlogs, railroad ties, poles, posts, fuel wood and nuts.

The sawlogs from the Kansas woodlots furnish excellent lumber for interior use in farm buildings. It is especially serviceable for joists, beams, studding, and sheathing for houses, and for floors and partition boards for bins and stalls in barns and sheds. For such uses our native lumber is more durable and more satisfactory than the pine lumber from the local lumber yard. A great many of our native logs are sawn into box boards and crating material at the local mills, and command a good price for such uses. In some sections of the state the native logs are in good demand at barrel stave and head factories. The cottonwood is recognized as one of the very best woods for staves for flour, vegetable and fruit barrels. The elm, hackberry, ash and soft maple are used extensively for barrel headings. The black-walnut logs are considered too valuable for local consumption, and the most of them are bought by wholesale walnut-log buyers and shipped to Eastern consumers. Second-growth hickory is in good demand at vehicle factories, and the cordwood finds ready sale

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at good prices at the packing-house centers, where it is used in smoking cured meats.

There are no reliable figures available that show the amount or the value of the woodlot products required annually, but the sum total for such a state as Kansas is immense. To understand fully the economic importance of the woodlot we must remember that the United States, as a nation, is cutting her timber supply at three times the rate of the growth of the timber in her forests, and that lumber prices are constantly and gradually advancing. This advance in price is bound to continue until the price of lumber equals the price of stone, brick, tile, and cement as building materials. These materials, and especially lumber, are bulky commodities, and the transportation rates greatly increase the cost to the consumer. All of these conditions increase the value of the products of the farm woodlot.

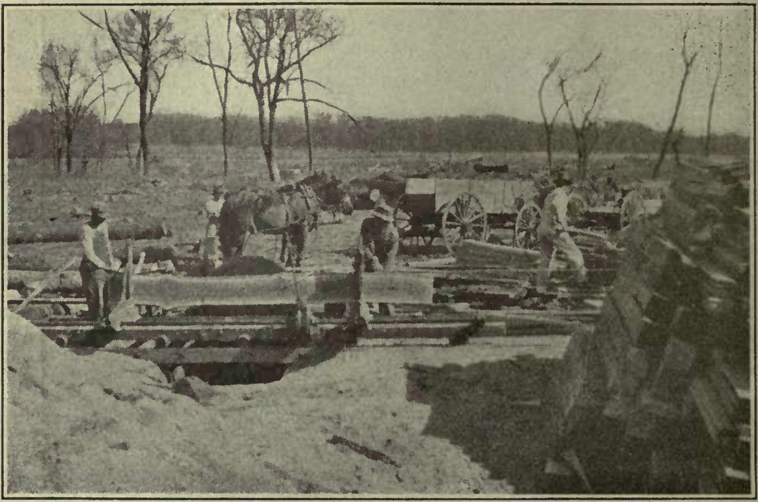

FIG. 159. Sawing lumber from a Shawnee county, Kansas, woodlot.

The term "woodlot" as used in this article includes all land within the state on which natural or planted timber is growing. There are approximately five hundred thousand acres of natural timber land within the state. This land is at present considered waste land by most of the owners, for the reason that the returns from it do not pay the taxes and a reasonable interest on the investment. The present stand of timber on this land is of little value, because of the fact that for the past fifty or sixty years the settlers and owners have gone into the woodlot from year to year and cut the best trees for their particular needs, and have left such kinds as the white elm, the hackberry, the soft maple, the sycamore, the basswood, the water oak, and like worthless species. These, because of their hardiness and ability to compete with other native vegetation, now occupy the ground that might well be producing such trees as the black walnut, bur oak, cottonwood, red cedar, or Austrian pine.

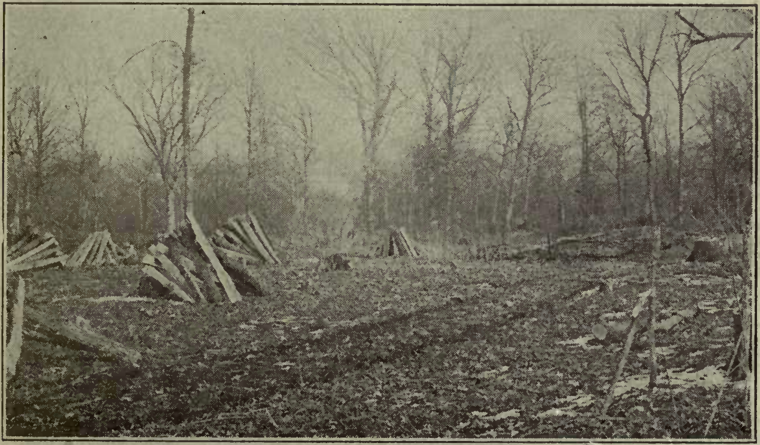

FIG. 160. A cut-over woodlot in fine condition to plant with acorns, walnuts, pecans, or with seedling trees of some desirable kind.

The problem to be solved in handling the woodlot is. How can the stand of trees be improved and the yield increased? If we want to grow a crop of corn we plant the seed and cultivate the growing crop; if we want to grow good fruit we prune and spray the orchard; if we want to grow high-grade lumber-producing trees we must choose the valuable kinds, plant and care for them as their demands require.

In the eastern half of the state the natural timber is found on three distinct types of land—the overflow land lying along the rivers and their tributaries, the steep hillsides facing these watercourses, and the gravelly and sandy land found in certain sections of the state. By far the greater area of this is included in the first class mentioned, viz., the overflow lands lying along the watercourses. This is the richest land within the state, capable of producing timber that will under proper management return a good profit and interest on the value of the land. The trees that are best adapted for such land are the cottonwood, black walnut, bur oak, and pecan.

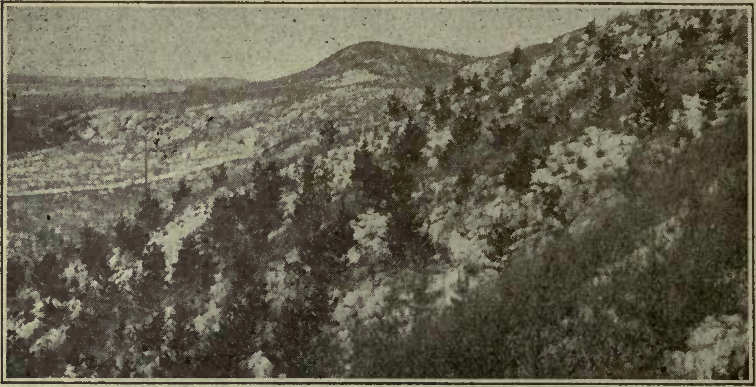

FIG. 161. A worthless sandy hillside that was planted with jack pine in 1903. This picture was taken in 1907. Fig. 162 shows the same hill as it appeared in 1915. —[*Courtesy Forest Service.*]

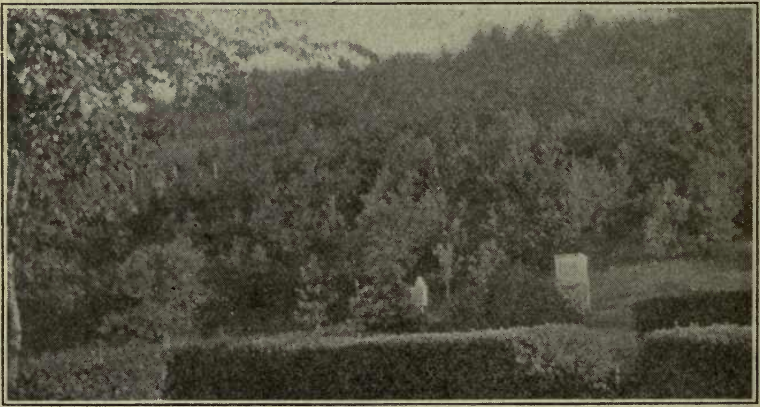

FIG. 162. The same hill that is shown in Fig. 161. This picture was taken in 1915.

The rough hillsides and steep slopes now supporting an unprofitable stand of black and red oak, hickory, ash, and other similar growth are capable of supporting a profitable growth of trees if the right species are planted. The trees that are peculiarly adapted to this type of soil are the native red cedar and the Austrian pine.

The gravelly and sandy land that is now occupied almost exclusively by post oak and blackjack is a very poor type of land, entirely unfitted for agricultural purposes. The post-oak land is too gravelly and sterile to produce agricultural crops, although when cleared it makes fair grazing land. When cleared and farmed the blackjack land soon becomes exhausted of its fertility and blows and drifts with the prevailing winds. Both of these types of land are capable of producing excellent tree growth when the right species are planted. The trees suitable for these soils are the red cedar, Austrian pine, and Chinese arbor vitæ.

Fig. 163. Clearing, burning brush, digging holes, and generally putting the land in shape for tree planting.—[*Courtesy American Forestry.*]

The kind of land and the character of the growth upon it must determine the details of the method to be employed in the improvement of the woodlot. However, the general system will be the same in all cases, and will consist of three distinct operations:

First. Thinning: cutting out all mature trees that are worth as much now as they will be at any future time, and all undesirable trees of all ages or sizes.

Second. Planting: restocking the land by planting seedling trees or seeds of desirable species.

Third. Protecting the young trees against injury from excessive growth of weeds, fire, or live stock.

THINNING.

The first step involves the greatest amount of work and possibly the greatest amount of expense. All the mature trees should be cut to make room for the smaller-sized trees now growing together with them, and to make room for planting seeds or seedlings of desirable trees for future crops. The undesirable trees of the present stand, regardless of their age or size, should also be cut so as to make room for as many trees of the more valuable species as possible. This cutting may be done by one of two systems—the *group* or *strip* system. The group system consists of cutting the trees in groups of irregular areas here and there throughout the woodlot. One or more groups are cut each year until the entire woodlot has been cut over. This system will probably be found to be the most satisfactory in the Kansas woodlots. The strip

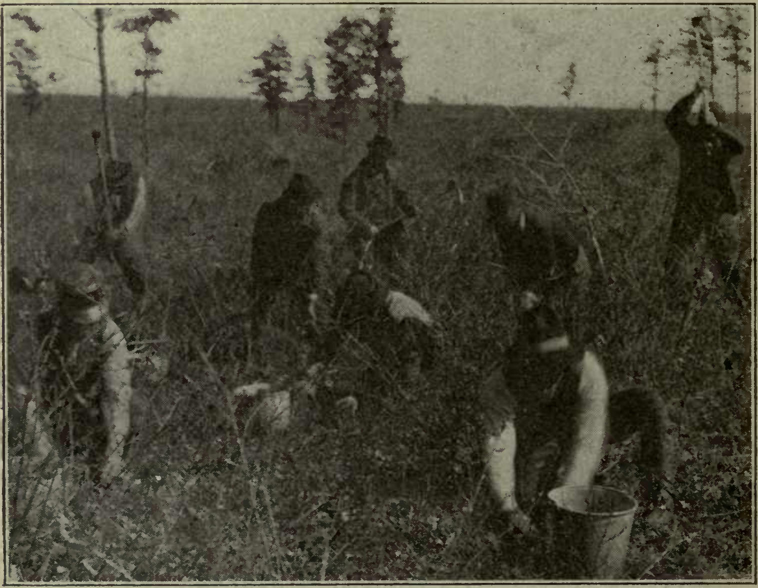

FIG. 164. A force of men planting evergreen seedlings on cut-over land.—[*Courtesy American Forestry.*]

system consists of laying off the woodlot in a definite number of strips of varying widths, and of cutting one strip a year until the entire woodlot has been gone over.

PLANTING.

In order that the woodlot may yield the greatest possible crop of wood the land must be kept fully stocked with growing trees. The number per acre will vary with the age and size of the trees. Prof. E. L. Sponsler, University of Michigan, is authority for the following table, which gives the number of trees at different sizes necessary to keep the ground fully stocked.

TABLE 1.—*Number of Trees per Acre Required for a Full Stand.*

Diameter.[1]	No. per acre.
2 inches	2,000
4 inches	900
6 inches	510
8 inches	320
10 inches	235
12 inches	170
14 inches	130
16 inches	100
18 inches	85
20 inches	75
22 inches	65
24 inches	55

To give a clearer idea of the spacing of trees in a full stand, the following table gives the number of trees per acre for the different spacings.

TABLE 2.—*Number of Plants Required to Set an Acre of Ground at the Given Distances.*

Spacing.	No. of plants.
3 by 7 feet	2,074
4 by 5 feet	2,178
4 by 12 feet	907
5 by 9 feet	968
6 by 8 feet	907
7 by 12 feet	518
8 by 10 feet	544
9 by 15 feet	322
10 by 15 feet	290
10 by 18 feet	242
10 by 20 feet	217
10 by 24 feet	181
15 by 18 feet	161
10 by 30 feet	145
12 by 30 feet	121
15 by 30 feet	96
18 by 24 feet	100
20 by 20 feet	108
12 by 42 feet	86
15 by 36 feet	80
12 by 48 feet	75
24 by 24 feet	75
18 by 36 feet	67
12 by 60 feet	60
15 by 48 feet	60
24 by 30 feet	60
15 by 54 feet	53
18 by 42 feet	57

The planting may be done at any convenient time after the thinning has been done. The best time and the best method to follow will be determined by the character of the ground and the kind of trees that are to be planted. Walnuts and acorns may be planted in the fall, soon after they ripen or early the following spring,[2] in holes four or five inches deep, made with a spade or mattock. Enough nuts or acorns should be planted to insure a stand of not fewer than 2000 seedlings per acre. This will require a plant on every 20 square feet of ground or on an area 4 by 5 feet in extent.

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[1] The diameter of a tree is measured at four and one-half feet above the ground.

If seedlings are used in restocking the woodlot they should be planted in March or April. These should be planted in sufficient numbers to insure a full stand of trees. (See Table No. 2 for spacing.) Because of the stumps and roots that are in the ground a regular spacing cannot be made, but enough trees can be planted to insure a full stand. Seedlings of the broad-leaved[3] species from 3 to 8 feet in height, and evergreens[4] from 15 to 24 inches in height will give best results.

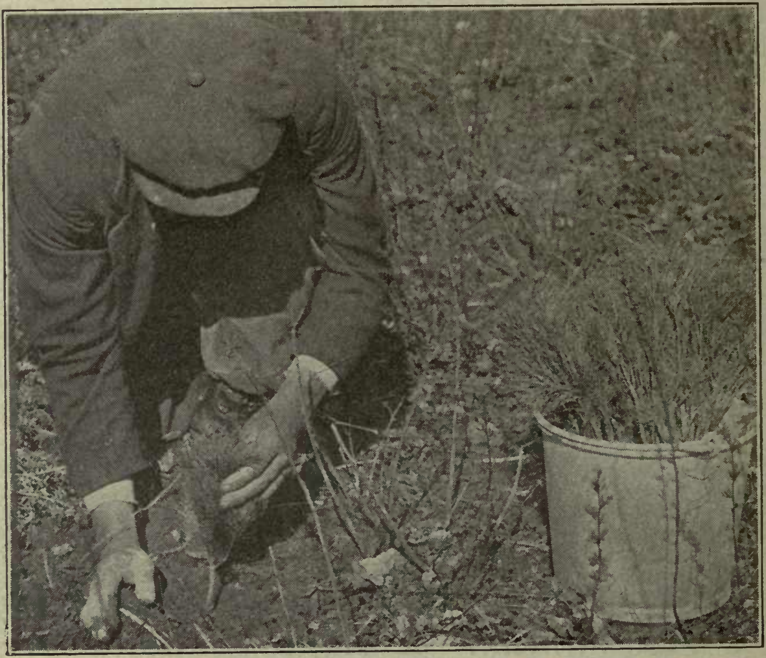

FIG. 165. Planting a pine tree in a cut-over woodlot. The short growth of brush will protect the pine from the sun and wind.—[*Courtesy American Forestry.*]

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[2] Whenever nuts or acorns are held over for spring planting they should be stratified soon after they ripen. Stratifying seeds of any kind consists of storing them in alternate layers with sand, soil, leaves, or straw, so as to prevent overdrying or heating of the seeds. Small quantities of seeds are stratified in boxes that are stored over winter in basement rooms, or buried in pits out of doors; large quantities of seeds are stratified in bins in basements. It is usually desirable to allow the stratified seeds to freeze and thaw throughout the winter with the changes of the weather.

[3] The term "broad-leaved" is applied to all forest trees excepting conifers or cone-bearing trees.

[4] "Evergreens" is a term generally applied to conifers, and is used to mean conifers in this article.

These must be planted in holes, dug with a spade, large enough to receive the roots spread in natural order.

The reason for planting the seeds and seedlings so much thicker than the trees can grow is in order to shade the ground as soon as possible, so as to keep down the weeds and to protect the ground from the drying effects of the sun and wind, and to develop trees with tall, straight stems, clear of large limbs to as great a height as possible. When not crowded trees develop short stems that divide into several large limbs near the ground, and are of little or no value for lumber, poles. or posts.

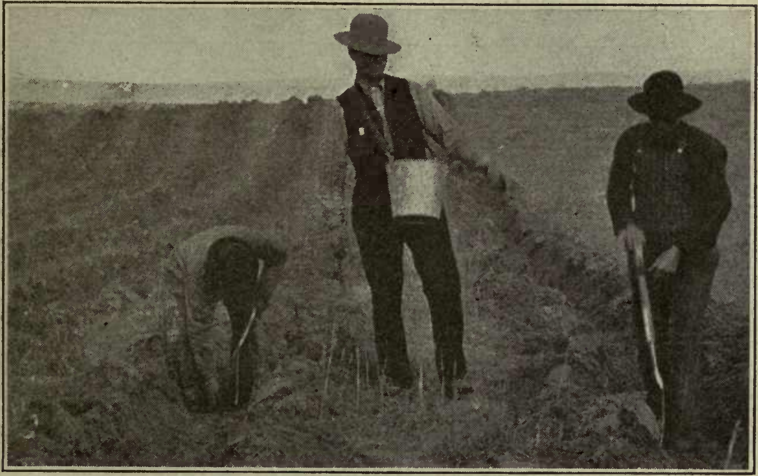

FIG. 166. A three-man crew planting evergreen seedlings in lister furrows. In this organization one man carries a supply of trees and two men dig holes and plant. —[*Courtesy Forest Service.*]

PROTECTION.

The first attention that newly planted trees will demand will be protection against weeds, which if not cut will overtop and shade them out. This protection should consist of cutting the weeds from an area of ground extending at least two feet in all directions from the tree. If all the weeds can be cut from among the trees so much the better. When only a part of the weeds are cut there is danger of fire during the fall, winter, and early spring months. Young trees are easily killed by fire, and protection against this source of danger is very necessary.

Young trees are seriously injured and often killed by live stock trampling the ground and eating the leaves and twigs.

It is therefore necessary that live stock of all kinds be excluded from the land growing young trees. This protection must be maintained until the trees are large enough to shade out the weeds and their tops high enough to be out of reach of live stock.

DESIRABLE TREES FOR KANSAS WOODLOTS.

Black Walnut.

The black walnut is a native tree throughout the eastern half of the state of Kansas and is the highest-priced wood on the market of any of our commercial American trees. The wood is used in the United States as shown below.

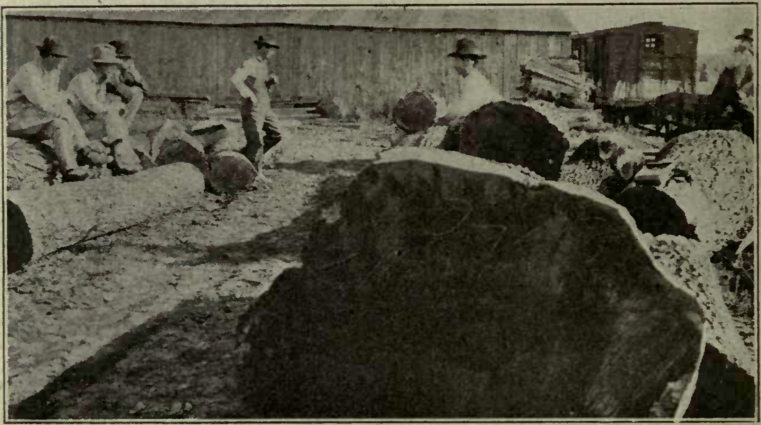

FIG. 167. Loading black walnut hauled in by farmers.—[*Courtesy Forest Service.*]

Factory Uses of Black Walnut.[5]

Purpose.	Per cent.
Sewing machines	33
Musical instruments	21
Mill work	19
Furniture and fixtures	10
Firearms	7
Caskets and coffins	2
Electrical machinery and apparatus	2
Vehicles	2
Car construction	1
Other uses	3
Total	100

In recent years the best grades of black walnut logs have largely been exported to European countries. However, in the past year or two the demand for walnut for American uses has greatly increased. Black-walnut furniture and finishing is now becoming very popular in the United States. The present prices of walnut logs vary, according to the size and quality, from $25 to $100 per thousand board feet on the stump.

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[5] The tables of factory uses for the various woods given in this article are taken from Kellog's "Lumber and Its Uses," published in 1914.

Range and Habit of Growth. The black walnut grows naturally throughout the hardwood region of the United States in mixture with other hardwood species. It is never found growing in pure stand, nor has it made an altogether successful growth when planted in pure stand. The black walnut is a tree which requires full sunlight, and should be planted only in mixture with trees of smaller size. The foliage of the walnut is rather sparse. This allows sufficient light to reach the ground to support a very satisfactory growth of the more tolerant[6] or shade-enduring species, such as the red cedar, the green or white ash, and the mulberry. The black walnut requires a deep, rich soil in which to make its best growth. Frequent flooding is not seriously objectionable, but the trees will not stand swampy conditions. Being highly intolerant as seedlings, they must begin their growth in the open. Under these conditions they make a rapid height growth, clearing themselves of limbs readily. By the time they have reached middle age they have attained their full height growth, and they must then have sufficient room to develop a broad, spreading top, in order to make a rapid diameter growth. The black walnut will reach its financial maturity[7] in from 75 to 100 years, at which age the tree should measure from 2½ to 3 feet in diameter at the stump.

The Yield. While no data is available to show what yield a full stand of black-walnut trees will cut, it is reasonable to expect that a stand of fifty trees per acre will at maturity yield not less than 15,000 feet board measure[8] of merchantable logs,[9] which at present value would be worth, at the very least, $3250. This is equivalent to a rental value of $32.50 per acre per year gross income on a 100-year rotation.[10]

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[6] Tolerance of trees refers to their ability to grow in the shade of other trees. A tolerant tree is a tree that will grow thriftily in the shade of some larger tree. An intolerant tree is one that demands full sunlight and will not live in the shade of other trees.

[7] Trees attain their financial maturity when the value of their annual growth falls below the cost of maintenance.

[8] One foot board measure is the unit of measure of lumber, and it is a board 12 inches long, 12 inches wide, and 1 inch thick.

[9] Merchantable log is a log that is salable on the market.

[10] Rotation is the length of time required to grow trees to merchantable size.

Cottonwood.

The common cottonwood is a native through the entire state. It grows the most rapidly and attains the largest size of any of our native species. The wood is light, tough, quite strong, and entirely serviceable for many purposes. It is most commonly used in this state for rough lumber for interior purposes. It is used especially for joists, studding, flooring for bins and mows, stall partitions, and sheathing. In the commercial trade it is used extensively for boxing and crating and for the manufacture of excelsior and fiber for plaster mills. The present price of cottonwood logs on local market is about $12 per thousand board feet.

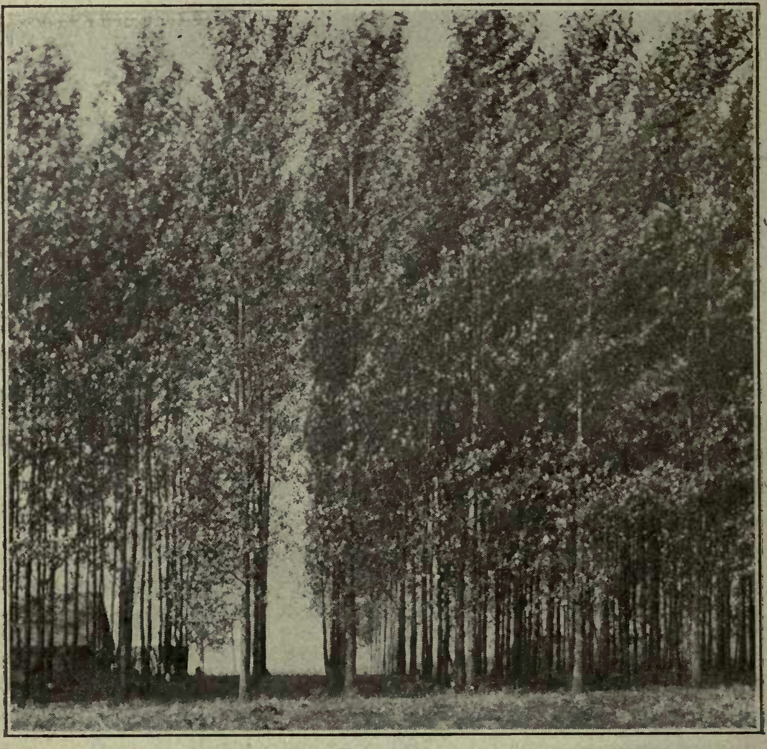

FIG. 168. Fine grove of cottonwoods ten years old, on low ground. Boles unusually straight and clear. Planted five by six feet apart; thinned to six by ten feet.—[*Courtesy Forest Service.*]

Factory Uses of Cottonwood.

Purpose.	Per cent.
Boxes and crates	56
Excelsior	14
Vehicles	9
Mill work	6
Agricultural implements	4
Woodenware and novelties	4
Furniture and fixtures	2
Refrigerators and kitchen cabinets	1
Other uses	4
Total	100

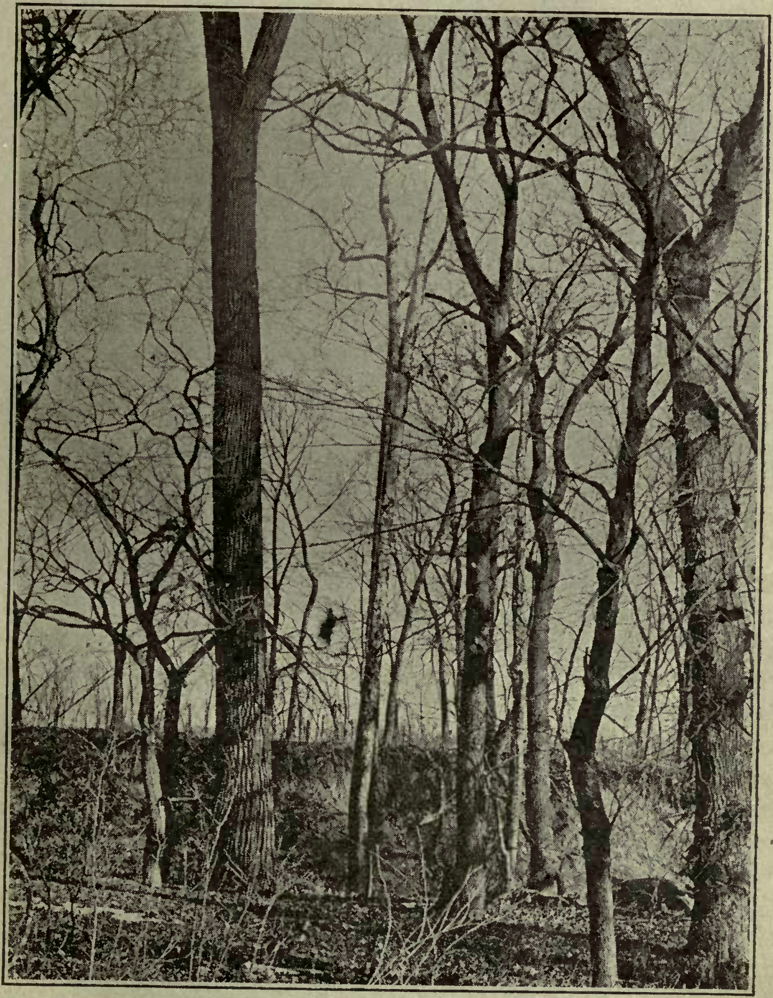

FIG. 169. A cottonwood (in the background), showing fine form. This tree will cut three sawlogs, each fourteen feet long, and all clear of limbs.

Range and Habit of Growth. The cottonwood is found growing naturally through the southern Mississippi valley region. It is found in great abundance along the watercourses and on low, rather wet soils, growing in mixture with hardwood species. The cottonwood requires full sunlight for its best growth. On account of the sparseness of its foliage it is a tree that will allow underplanting of some of the more tolerant species, such as the red cedar, mulberry, white or bur oak. The cottonwood will grow successfully in any soil in which there is an abundance of moisture, but it makes its best growth in deep, rich soils. Under these conditions the trees make a very rapid height growth, clearing themselves of limbs readily, and at twenty years of age will have practically attained their height, which will vary from 75 to 100 feet, depending upon the strength of the soil. From this time on the rate of growth in diameter is quite rapid, until the trees are from thirty-five to forty-five years of age. At twenty years of age some sawlogs can be cut from the stand, but the majority of the trees will not reach merchantable size until thirty years of age. The maximum yield is attained when the trees are about forty years of age. The following growth and yield table for cottonwood is taken from Bulletin 24 of the U. S. Department of Agriculture. The data from which this table was compiled was gathered from 1950 saw mills located throughout the Mississippi valley region.

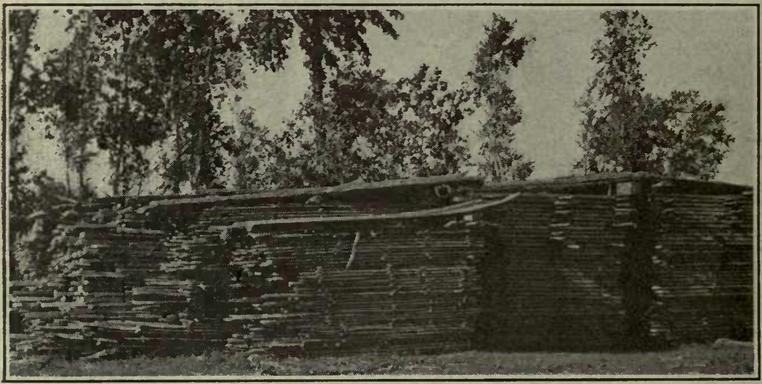

FIG. 170 Lumber cut from cottonwood logs from a planted farm woodlot in Reno county, Kansas.

Growth and Yield Table of Cottonwood in Pure Fully Stocked Stands in the Mississippi Valley.

Age of tree in years.	Number of trees per acre.	Average D. B. H.* inches.	Average height in feet.	Yield per acre.	
				Stem wood.	Board feet.
5	....	2.0	22	650	....
10	699	5.7	56	1,800	....
15	276	9.2	81	3,850	2,400
20	163	12.3	97	4,900	6,600
25	114	15.0	108	5,450	11,900
30	80	17.4	115	5,825	20,300
35	59	19.7	121	6,150	29,400
40	49	22.0	127	6,425	31,000
45	42	24.2	132	6,675	29,500
50	32	26.5	136	6,900	29,400

*The initials D. B. H. mean "*diameter breast high*," which is four and one-half feet above the ground level.

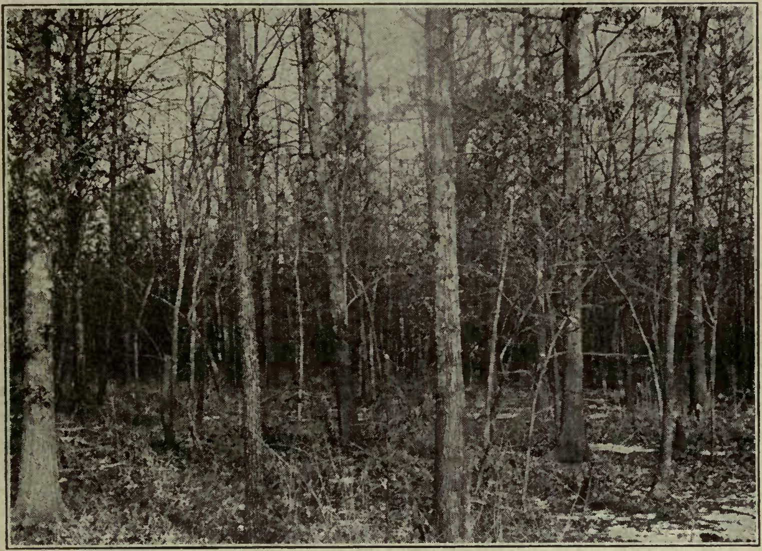

FIG. 171. A fine stand of second-growth oak. This woodlot will at some future time cut a lot of good logs, poles, posts and fuel wood.

Yield. The cottonwood will probably return the greatest financial yield per acre per year of any tree that is suitable for woodlot planting. As shown in the accompanying table, a normal yield at forty years of age is thirty thousand board feet per acre, which at $12 per thousand is $360 per acre, equivalent to a rental value of $9 per acre per year. There is no other species that can be planted in this state that will yield more than half this amount of lumber in the same length of time. Because of its rapid rate of growth it requires less attention and cultivation than any other tree. It is a tree that is comparatively free from injurious insect attacks or from fungous diseases until it has reached maturity. The demand for the cottonwood lumber is good and will continue to increase. Inasmuch as it is a lumber that can be used generally on the farm, it merits a place in every farm woodlot for the production of farm timber supplies.

Bur Oak.

The bur oak is native throughout the hardwood region of the United States, and is found growing naturally throughout the eastern half of Kansas. On favorable soil and in protected locations it can be grown very successfully in the woodlots. The wood of this species is hard, heavy, strong, and very durable in contact with the soil when thoroughly seasoned. It is a wood that can be used in almost every way on the farm, makes excellent posts, framing timbers, bridge planks, railway ties, and material for general repair purposes. The mature trees are in demand for lumber purposes. It is one of the valuable woods for factory uses, which are as follows:

Factory Uses of Oak.

Purpose.	Per cent.
Furniture and fixtures	32
Mill work	25
Car construction	15
Vehicles	11
Agricultural implements	3
Boxes and crates	3
Ship and boat building	2
Refrigerators and kitchen cabinets	1
Musical instruments	1
Sewing machines	1
Other uses	6
Total	100

Range and Habit of Growth. The bur oak grows in mixture with the other hardwood species. It is seldom found growing in pure stand. As a seedling it will endure considerable shade, but it requires light from above to develop its best form and to make its most rapid growth. When grown in thick stands as saplings they develop tall, straight stems with few limbs. By the time the trees reach middle age they demand full light, and with the approach of maturity develop broad, spreading crowns with massive trunks. The foliage of the bur oak is very dense and allows but little light to strike the ground. To make its best growth it requires a deep, rich, fresh soil, but grows remarkably well on rather heavy gravelly soils. Being tolerant in youth, the acorns of this species may be planted in partially shaded situations, especially where the shade is from the side rather than directly overhead. When grown in the open with full light the bur oak develops a short trunk with many heavy limbs. This type of tree is of little value except for fuel and posts. The best form of oak is always developed in dense stands or in partly shaded situa-

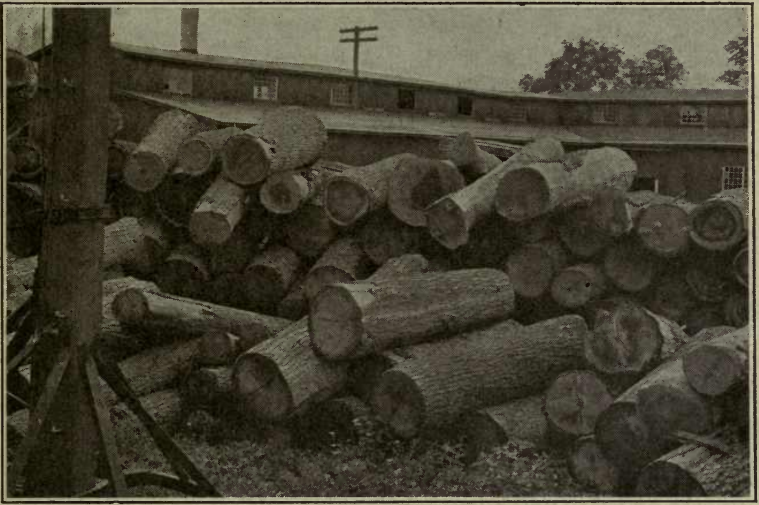

FIG. 172. White oak and red oak logs at mill, having been shipped by rail from farm woodlots a distance of about twenty miles.—[*Courtesy Forest Service.*]

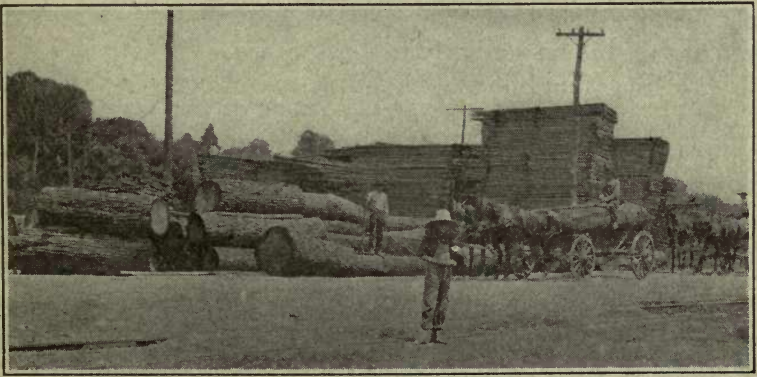

FIG. 173. White and red oak, and some hickory, from small farm woodlot.—[*Courtesy Forest Service.*]

tions. The bur oak will reach maturity in from 75 to 100 years, at which age the trees should be from 2½ to 3 feet in diameter at the stumps.

Yield. There are no figures available to show what yield may be expected from a full stand of bur oak. However, the cut in logs at maturity should be not less than 15,000 board feet per acre. The present stumpage price varies from $12 to $25 per 1000 board feet. As the oak is a valuable post timber, no doubt the greater part of it will be used for posts and ties.

Pecan.

The pecan is one species of hickory, which grows naturally throughout the southeastern fourth of the state. While the wood of this tree is not considered of any great commercial value, the nuts that the tree produces command a good price, and under proper care the trees yield a good crop, which in many instances will equal or exceed in value the agricultural crop that may be produced on land suitable for growing pecans. The soil along the watercourses in the southeastern fourth of the state is entirely suitable for pecan growing, and many farmers are now considering the possibility of growing such a crop.

An investigation of the conditions under which pecans grow most successfully shows that the trees are well adapted to a variety of soils, but that they make their best growth and attain the largest size on deep, rich, moist soil. They will grow in swampy conditions, but prefer a well-drained soil. Trees have been found growing on dry, gravelly or stony soils, but in such soils their rate of growth is slow and the trees are small and scraggly in appearance.

Up to this time but very little has been done in this state to determine what is possible in the way of developing an improved strain of our native pecans. There are great possibilities along this line. The so-called paper-shelled pecans of the South are not hardy under our conditions and cannot be used for planting stock. The nuts of our native species are small in size, but the quality is excellent. The shells of some of our native nuts are extremely heavy, while on others the shells are very thin, comparing favorably in thinness with the so-called paper-shelled nut of the South. A careful survey of the state would undoubtedly reveal some unusually large nuts with medium or thin shells, from which seedlings from the ordinary nuts might be budded.

If a desirable nut can be developed in this way there is a great possibility of growing pecans profitably on large areas of overflow land along the Marais des Cygnes, the Neosho and the Verdigris rivers and their tributaries. The pecan trees in this section of the state, growing under natural conditions, frequently attain a diameter of three and one-half or four feet, and vary from seventy-five to ninety feet in height. Mature trees are known to have yielded as much as 600 pounds of nuts in a single season. However, the nut crop under natural conditions occurs periodically. There are a few nuts practically every year, and occasionally there are extremely heavy crops.

System of Management. The pecan is propagated from the nuts. These should be planted in the fall or stratified until spring and planted in March or April before they begin their growth. The ground in which the nuts are to be planted should be under a thorough state of cultivation. The nuts should be planted in rows or at regular spacing at the rate of from 3000 to 5000 per acre. When two years of age the seedlings should be budded with buds from the best stock available. This work should be done during August. The following spring the tops should be cut off the seedlings on which the buds have set. The bud then throws out a shoot which develops into the future tree. When five years of age the budded trees are transplanted to their permanent location. Cultivation must be continued until the trees reach such size as to thoroughly protect the ground by their shade. Some authorities on growing pecans maintain that cultivation should continue as long as the trees live and that the size and quality of the nut is greatly improved by continuous cultivation. Cultivation at least maintains a better supply of soil moisture than it is possible to maintain without tillage.

At twelve to fifteen years of age the trees come into bearing, and at twenty years of age should produce enough nuts to be of considerable value, the quantity of nuts continuing to increase with the increase of the size of the tree. The land on which pecans are most likely to yield a profitable crop is the overflow lands along the streams mentioned. Flood waters

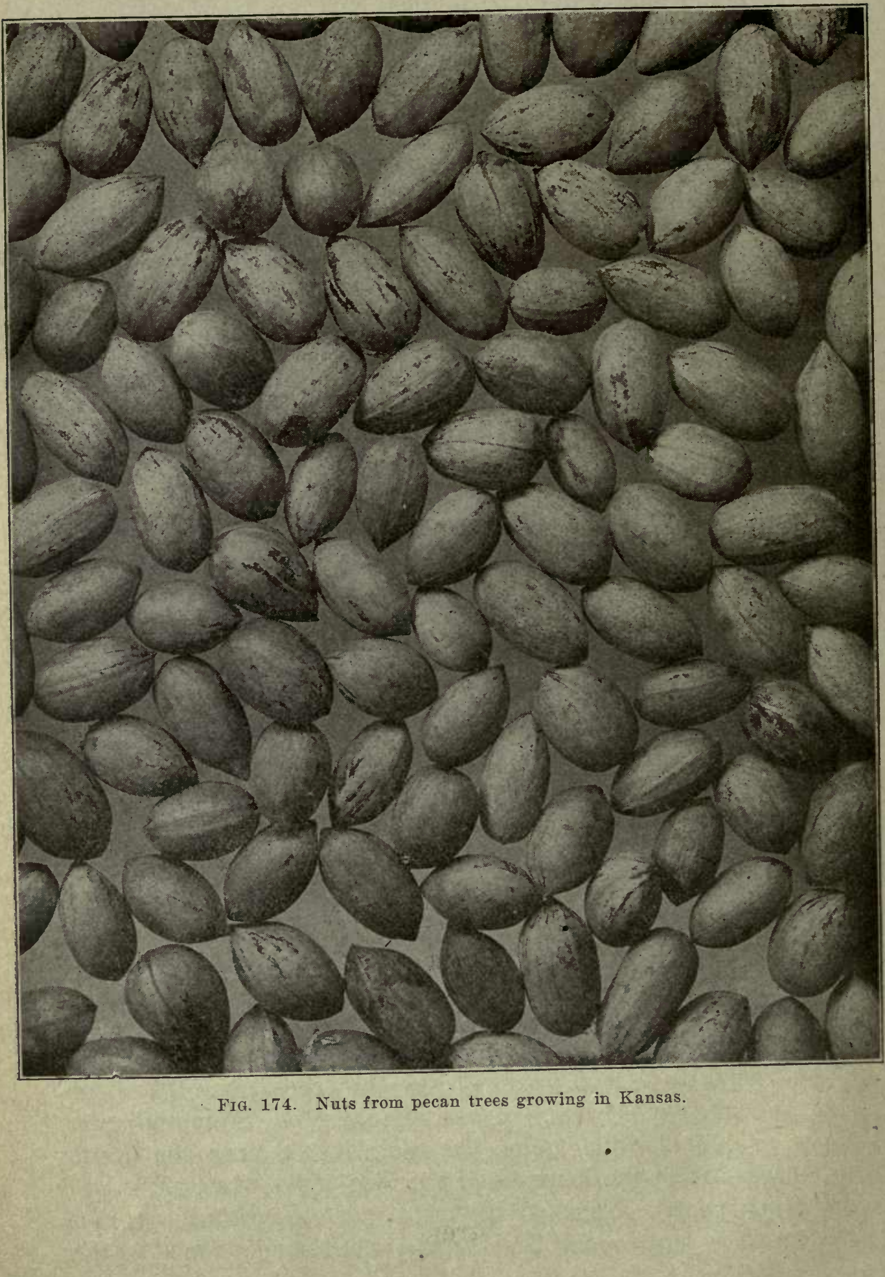

FIG. 174. Nuts from pecan trees growing in Kansas.

are in no way harmful to the growing trees, after they have reached sufficient size not to be completely submerged. Agricultural crops on this character of land are very uncertain, and because of their uncertainty grain farming is not a profitable enterprise.

Value of the Nuts. The market price of the nuts varies from year to year, presumably based upon the supply and demand. In years when the nut crop is heavy prices go down; when the nut crop is light the price advances. The range of fluctuation is from 7 to 12 cents per pound on the local market. Selected strains would produce nuts of uniform size and shape, and would, because of the cultivation given the tree, be larger than our common nuts and would command a better price. The selling price of the so-called paper-shelled pecans of the South, which are from one-third to one-half larger than our native species, is from 30 to 50 cents per pound.

The local supply of nuts is bought and used by wholesale confectionery concerns located in St. Louis and Chicago. The shelled pecans found on our local market are nuts of some of the improved budded varieties, mostly from Texas, some of the more hardy of which it may be possible to grow successfully in this state. Those that are most likely to give satisfactory results are the Busseron, Indiana, Niblack, Major and Warwick. These varieties are being grown successfully as far north as southern Indiana and Illinois.

The value of any nut meat of the pecan depends largely upon separating it from the shell without breaking or crushing the meat. In order to remove the shell with the least danger of injury to the kernel, the nuts should be steamed or steeped for a few minutes in hot water. This softens the shell and makes the nut meat more pliable and greatly reduces the danger of cracking or breaking it when removing the shell. There are a number of nutcrackers on the market. Among these the Squirrel, the Perfection, the Eureka, and the Bostrom are improved types that crack the shells very satisfactorily without seriously injuring the nut meats. Steaming or steeping the nuts, however, adds greatly to the ease with which the shell can be cracked and separated from the meat.

Use of Nuts. The use of nut meats in American homes has greatly increased in the past ten or twelve years. They are used extensively in nut loaf, in bread, in salads, and shelled, as an article of diet. However, the greatest use for the meat of the nuts is found in the wholesale confectionery trade.

Red Cedar.

The red cedar is the only coniferous tree that grows naturally in this state. The wood is of special value for specific purposes. It is used exclusively in the manufacture of all high-grade lead pencils, which calls for absolutely clear wood.

FIG. 175. Grove of pecans that yields heavy crops of nuts.

In recent years the cedar-chest industry has developed rapidly in this country, and a large quantity of inferior lumber, containing knots, sapwood and other defects that disqualify it for use as pencil wood, is used in this industry. Smaller-sized, knotty material, unfit for the cedar-chest industry, is used extensively as posts and poles. The red-cedar wood is the standard of durability of all native timbers. It is practically indestructible to decay. Cedar posts command a higher price than any other post on the market. The only criticism to the red cedar for this purpose is that it is not strong enough to resist a severe strain when the ground is frozen, and the posts generally break off squarely at the surface of the ground at such times. During the months when the ground is not frozen they are absolutely satisfactory in every respect.

Range and Habit of Growth. The red cedar grows naturally throughout the greater part of the United States from Maine to Florida, and from Florida northwest across the plains states to the Rocky Mountain region and British Columbia. Throughout the New England states they are found growing on all types of soil, excepting in swampy, wet situations. In the southern states they are a swamp-type tree. Throughout the plains states and the western mountain regions they are found occupying the bleakest and most exposed situations on north and northeast slopes. This range of habit indicates their

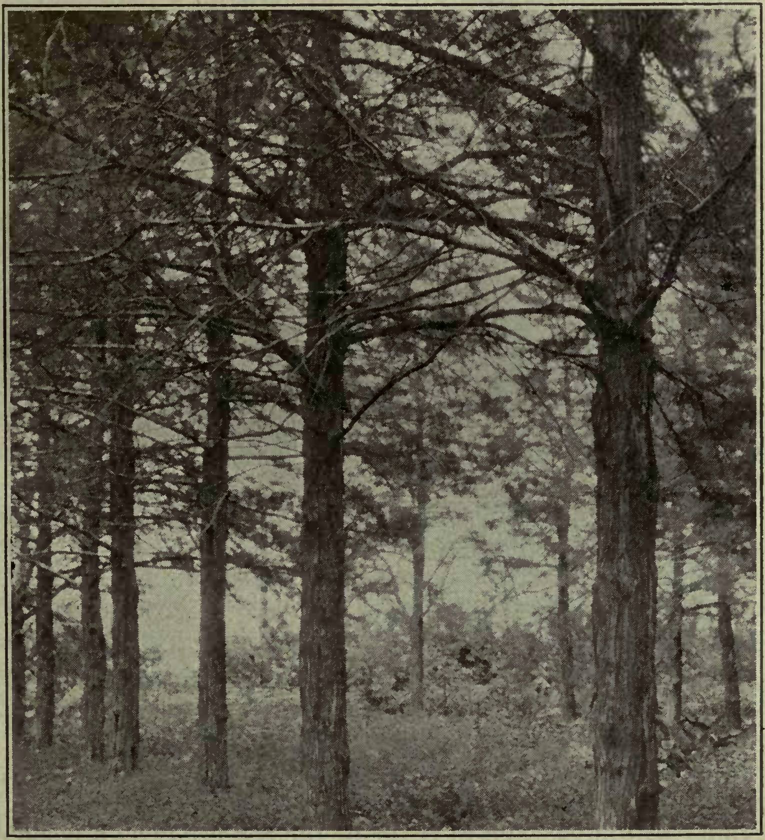

FIG. 176. Red cedar trees in a farm woodlot. These trees are forty-two years of age, and will cut twelve posts each.

adaptability to the various soils and conditions under which they will grow.

In this state we find the cedar in definite areas in different portions of the state, principally throughout the limestone section, and in some instances in the districts having sandstone outcroppings. In these different districts the red cedar first gained foothold on the protected sites with north and northeast exposures, and since the trees have reached maturity and produced seed they have gained a foothold on practically all types of soil, and are now found growing abundantly over the tops of many of our limestone hills, as well as in the deep rich soil found in the bottom lands along the watercourses.

It is a tree that is found growing in pure stand only in the southern states, and grows vigorously either in pure stand or in mixture with hardwoods. It is a highly tolerant tree during youth, but demands full sunlight by the time it reaches middle age. The foliage is very dense and will not permit of underplanting. Being highly intolerant, the trees do not clear themselves readily of limbs, and for this reason few clear stems can be developed except in very dense stands.

The green foliage of the cedar will burn as rapidly as the dry leaves of any other species, and once stripped of its leaves the tree will die. Little thinning will be necessary in a red-cedar stand until the trees have reached pole size, when it will be necessary to thin the trees in order to induce diameter growth. The material removed in such a thinning will make stakes and posts. The remaining trees will reach their financial maturity when between fifty and seventy-five years of age.

Yield. The ultimate product will be posts and poles. At the present time it is impossible to buy red-cedar posts on our local market excepting through special orders. A conservative estimate of the number of posts per acre at fifty years of age will be from 3500 to 4000 posts per acre. This is estimating the final stand to be spaced at 10 by 15 feet, and estimating that each tree will cut 12 to 15 posts each, which is not more than can be expected. At 20 cents per post this gives a gross return of $700 or $800 per acre, equivalent to an annual rental of $14 or $16 per acre.

One great advantage in favor of the red cedar as a woodlot tree in this state is that it is entirely adapted and suitable for planting throughout the entire state. There is not a quarter section of land in the state of Kansas on which red cedar cannot be grown successfully. It is the hardiest tree growing within the state. It has endured, without serious injury, the severest weather conditions that western Kansas has experienced in the past fifty years. It suffers less injury from hail and wind than any other tree that has been tried in western Kansas. The only objection that can be raised to the growing of red cedars in the woodlot is the fact that it is a host to a fungous disease known as the cedar apple, which in another form attacks and injures apple trees and fruit. It occurs on the apple leaf as rust and on the fruit as scab. However, this injury can be prevented by spraying with a fungicide, and inasmuch as it is impossible to grow apples in this state without spraying for both insects and fungous diseases, this fungus can be readily held in check with the same spray that is applied for other fungous diseases.

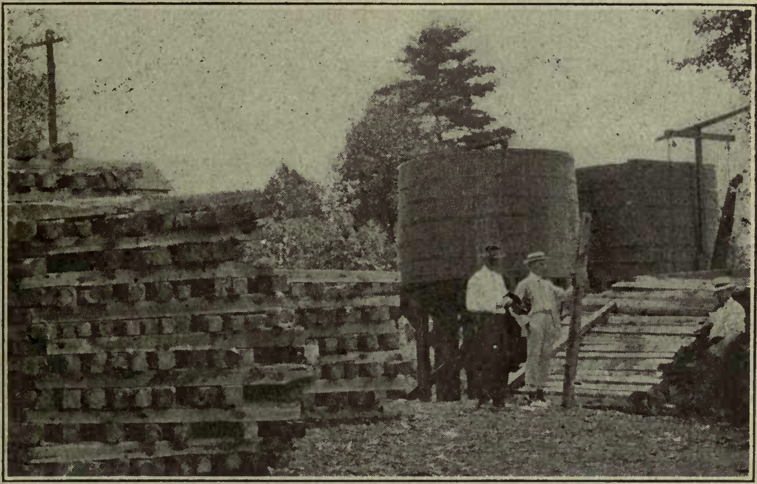

FIG. 177. Red cedar posts grown in a farm woodlot.—[*Courtesy Forestry Service.*]

Austrian Pine.

The Austrian pine is an introduced species from Europe. It has been planted extensively throughout the eastern half of the United States, where it has grown with much vigor and has proved a very satisfactory tree for protection and ornamental planting. When planted in dense stands the trees clear themselves readily of limbs and develop straight trunks of good diameter. The wood is straight-grained, of moderate weight, strong, and makes a very satisfactory lumber. The Austrian pine is well adapted to planting in woodlots throughout the eastern half of the state.

Habit of Growth. The Austrian pine is an intolerant species, and must be planted in open situations where it will receive full sunlight. It attains its best growth and development in deep, rich, rather moist but well-drained soils. It grows remarkably well on light sandy soils or on thin gravelly clay soils, but on the latter types of soil its rate of growth is considerably slower than on the bottom type.

Three- and four-year-old seedlings of this species, which will range from 15 to 18 inches in height, should be planted in pure stand, either on any cleared land or on old tilled fields or on steep gravelly or stony hillsides. These seedlings should be spaced approximately 6 by 6 feet, which will require 1200 seedlings per acre. They will demand the same general care and attention that is required by other trees. By the time the trees reach middle age it will be necessary to do considerable thinning, at which time the inferior specimens should be removed. This cutting will yield considerable fuel, and perhaps some poles that can be utilized for other purposes. The final stand will reach maturity when from sixty to seventy-five years of age.

Yield. The ultimate cut will be sawlogs that will measure from 18 to 35 inches at the stump. In good situations the yield should approximate 15,000 to 18,000 board feet per acre. In European countries the Austrian pine figures extensively in the turpentine industry. The bleeding is continued over a period of twelve or fifteen years prior to the maturity of the crop and final cutting.

The Austrian pine is absolutely free from injurious insects and fungous diseases, and no objection can be raised to its use from these standpoints. The greatest objection at the present time to its use in the woodlots is the high cost of the planting stock.

Sugar Maple.

The sugar maple is a native tree along the eastern border of the state, and grows with much vigor on the rich, deep soils

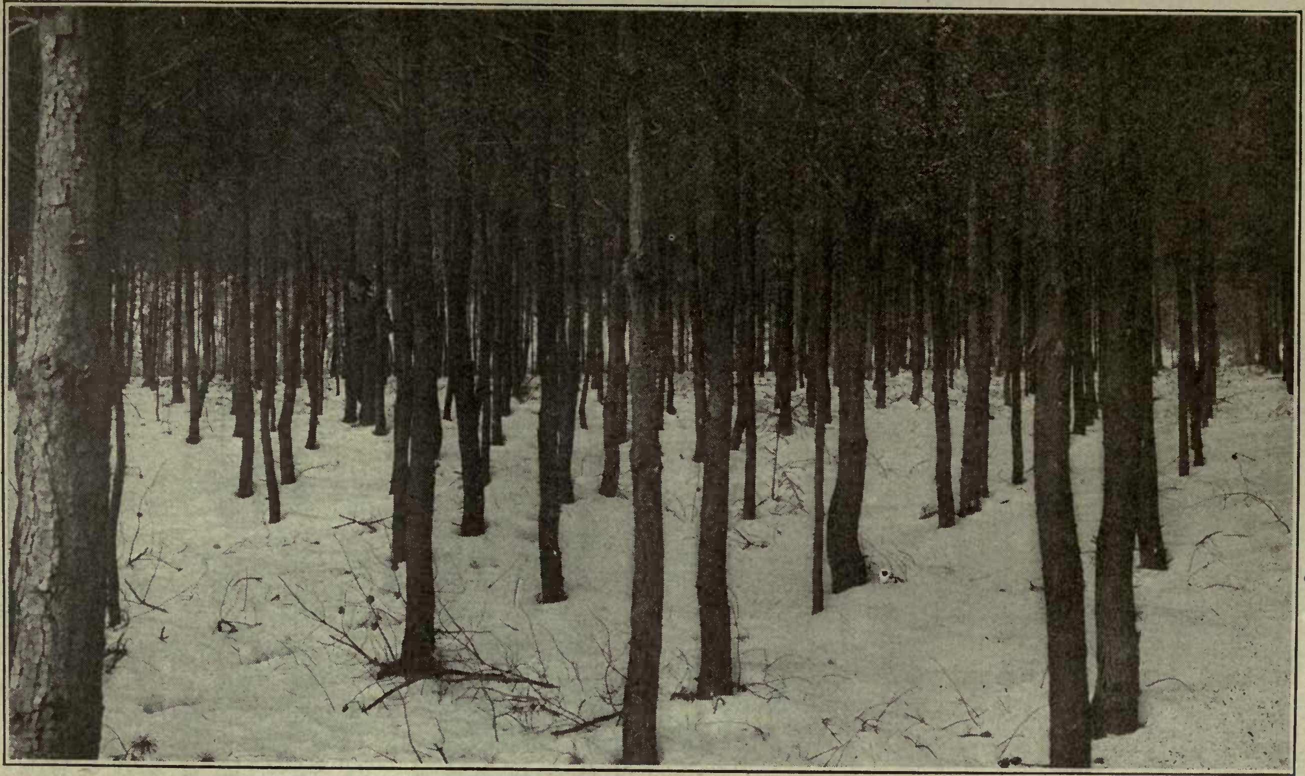

FIG. 178. A fourteen-year-old pine woodlot. The trees are growing in poor clay soil. All the surface soil was washed or blown away while under cultivation. Originally this was prairie land in eastern Kansas.

along the watercourses and up over the steep hillsides and bluffs on the eastern and northern exposures. This tree is a native through the greater part of the central hardwood region, growing in greatest abundance in the extreme north. The wood is heavy, hard, tough, strong, light colored, and used extensively in the manufacture of furniture, interior finishing, flooring, and in many ways in the various industrial arts, as shown in the following table:

Factory Uses of Maple.

Purpose.	Per cent.
Mill work	34
Furniture and fixtures	17
Boxes and crates	10
Boot and shoe findings	6
Agricultural implements	5
Musical instruments	5
Handles	4
Woodenware, novelties, etc	4
Vehicles	4
Laundry appliances	2
Other uses	9
Total	100

Habits of Growth. The sugar maple is one of the most tolerant of our broad-leaved species, growing as seedlings in dense stands under other hardwood trees, and even in mixture with conifers. In dense stands it clears itself readily of limbs and develops a narrow, conical crown, until it begins to approach maturity. The crown then assumes a more dome-like appearance, with compact, dense foliage. In this state the trees reach a diameter of three feet or more and a height of sixty feet or more. It is a tree that does not endure extreme heat or droughty conditions, and can only be grown successfully in this state where soil and atmospheric moisture conditions are congenial.

Two- or three-year-old seedlings of the hard maple may be used in woodlot planting to underplant maturing stands. When planted in this way the seedlings will require very little care, unless lopping the weeds is necessary to prevent the trees from being smothered. However, this will seldom be necessary if the stand is at all dense. In open stands hoeing and lopping the weeds will be required at least two or three years. Eight hundred or one thousand seedlings per acre will give a very full stand of hard maple.

Yield. The principal returns from the hard maple will be that of sap for syrup or sugar, and the planting should be made with the idea of maintaining a sufficient stand to shade off lower limbs. Trees with full crowns and an abundance of foliage yield the greatest amount of sap, and the planting should be made with this object in view. One thousand trees per acre are entirely too many to allow to grow to maturity. When they begin crowding each other fully half of the trees may be tapped and bled to death during a period of three or four years. These should then be cut out to make room for the remaining trees, which should grow until they reach a diameter of from 12 to 15 inches before tapping is begun. From this time on, by careful management, they may be bled annually without serious loss or injury to the trees.

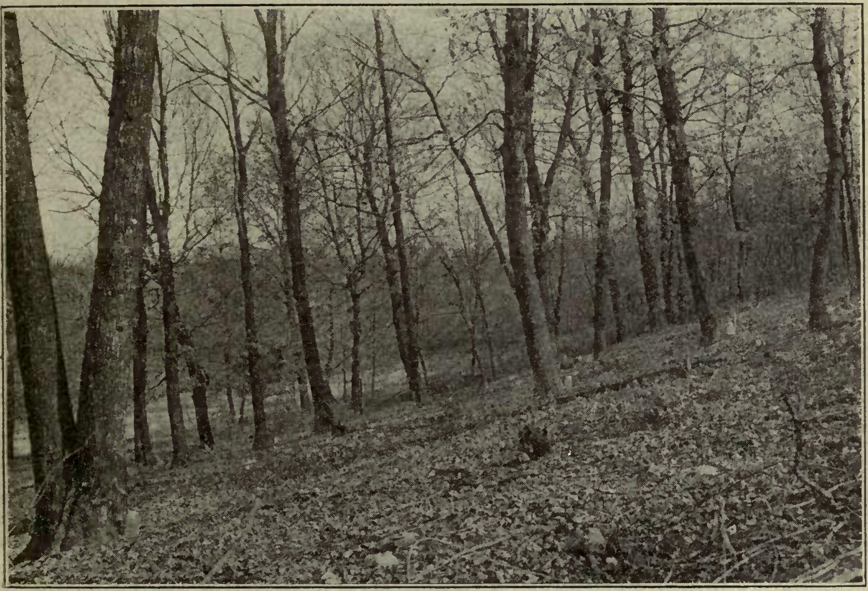

FIG. 179. A grove of sugar maple trees growing in Linn county, Kansas.

No very definite data can be given on the yields from the maple industry, as so many factors enter into consideration. From 5 to 40 gallons of sap are obtained from a tree during a season; an average is somewhere between 10 and 20 gallons. Normal sap of an average year contains about 2 per cent of sugar, although it may vary from .5 per cent to as high as 7 or even 10 per cent. The sugar content varies greatly with the tree, its location and its past growth. A single tree will yield from 1 to 7 pounds of sugar per season, or expressed in syrup of standard density, from 1 pint to 1 gallon, though the average from year to year and from tree to tree is about 3 pounds of sugar or 3 pints of syrup. Expressing these data in other terms, it is seen that in a normal year one barrel of sap (32 gallons) should produce a gallon of syrup or 7½ pounds of sugar. In many camps and for many years it takes sometimes as high as 50 gallons of sap to make 1 gallon of syrup. First runs of sap are generally richer in sugar, hence take less for a gallon of syrup. From 6½ to 9 pounds of sugar, according to the kind, can be made from 1 gallon of standard syrup, with an average of 7½ to 8 pounds. A camp of 100 trees should produce about 40 gallons of syrup or 300 pounds of sugar during a season.

Chinese Arbor Vitæ.

The Chinese arbor vitæ is an evergreen tree, generally of low, compact growth in its native habitat—the dry, rocky mountains of northern China. When planted in good soil under favorable climatic conditions the trees attain a height of 60 feet and a trunk diameter of from 5 to 6 feet. They reach their best development in a deep, fertile soil, and they resist even a considerable amount of alkali. According to Chinese observations, these trees are known to live to an age of more than 2000 years. The old specimens develop a very characteristic ragged and irregular outline, and are striking objects in the landscapes in northern China.

This tree thrives especially in those parts of China where the summers are hot and fairly dry, with an annual rainfall of between 15 and 25 inches, practically all of which falls during the months of July, August and September. The summer temperature in this region frequently reaches 110 degrees in the shade, while in the mountainous regions, where the tree grows under natural conditions, the winter temperature falls to 10 degrees below zero. The Chinese arbor vitæ will withstand a greater degree of cold than this if the winters are dry, but will not endure the cold in moist climates. The soil, moisture, and temperature conditions demanded by this tree prevail throughout the western two-thirds of the state of Kansas.

System of Management. The Chinese arbor vitæ is a highly intolerant tree, and the two-year-old seedlings or transplants must be planted where they will receive full light from overhead. Methods of planting and protection of this tree are identical with those advised for growing the red cedar. It is a tree that can be used to a good advantage in the rocky, dry soils and steep hillsides throughout the eastern part of the state, and it is an especially valuable tree for planting throughout the western part of the state. When planted in dense stands of from 2000 to 3000 plants per acre, the trees develop tall, straight stems that make excellent posts and poles. When spaced more widely the trees develop rather broad, spreading limbs and are valuable for windbreaks.

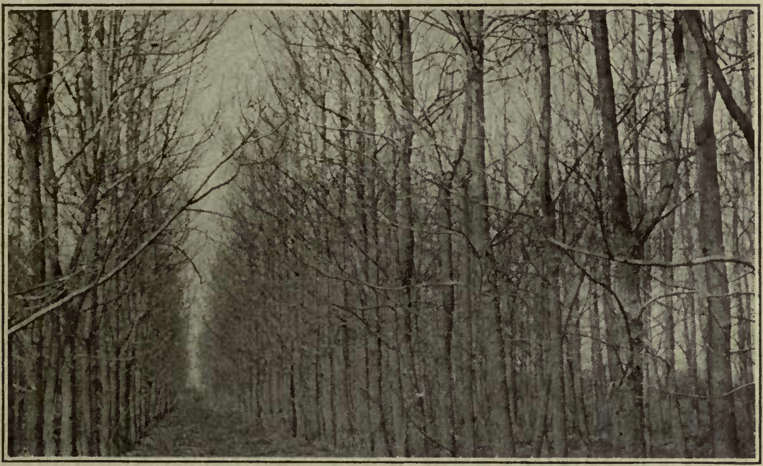

FIG. 180. Eight-year-old catalpa trees in a farm woodlot in Sedgwick county, Kansas.

There are two distinct forms of this species. One form grows erect with ascending limbs and is a valuable tree for the purposes mentioned. The other form is a dwarf type that grows very compact and symmetrical, and is prized highly for ornamental planting. It is one of the most beautiful of our ornamental evergreens. The two types are readily distinguishable in the nursery when the trees are two or three years of age, and the different forms should be selected and planted for the purposes they best fulfill.

In general appearance the tree is very much like the American arbor vitæ. The leaves are scale-like, closely appressed. Through the summer they are deep green, changing with the approach of winter to a rusty brown, again becoming a bright green during the first few warm days of spring.

Hardy Catalpa.

The hardy catalpa is a tree that has been planted quite generally throughout the state and most abundantly throughout the central section, where the well-cared-for plantations have proved very profitable. The wood of the catalpa is light brown in color and light in weight, but when seasoned is very durable in contact with the soil. Its principal use is for posts and poles.

Range and Habit of Growth. The hardy catalpa is found growing naturally in southern Illinois and Indiana, western Kentucky and Tennessee, southeastern Missouri, northern Arkansas, western Louisiana, and eastern Texas. In its natural distribution it is a tree that frequently attains a height of from 60 to 80 feet, with a diameter often measuring 3½ or 4 feet. In Kansas it is a small-sized tree, seldom exceeding 40 feet in height or 2 feet in diameter. It is a tree that is well adapted to the soil and climatic conditions of the eastern half of the state, but it is not a tree that can be recommended for the western portion. It should be grown in pure stand and planted only in deep, fertile, cultivated soil. The soil requirements of the catalpa are similar to the soil requirements of corn, and any soil capable of producing a good yield of corn will produce a good growth of catalpas.

System of Management. One-year-old seedling trees should be planted in rows 7 feet apart and set about 3 or 3½ feet apart in the rows. These may be planted in alternate lister furrows. When set the roots may be partly covered with a spade by hand and the furrows later filled in with a cultivator. The trees should be given at least two seasons' cultivation. Thorough cultivation during this time is very necessary to keep down the growth of weeds and to stimulate as rapid a growth of the trees as possible. By the third summer the trees should have attained sufficient size to shade the ground completely and to keep down all weed growth. Under these conditions they will make a rapid growth. When from 14 to 18 years of age they will have attained their financial maturity, and should then be cut. The cutting should be done in the winter and the ground should be cleared at one cutting. This will allow a growth of sprouts from the stumps to make a second crop, which in about twelve years will afford another cutting nearly equal to the first.

The Yield. The yield for a catalpa plantation will vary with the quality of the soil and with the care that the trees have received. On favorable soil, under this treatment, it is safe to count not fewer than 3500 posts per acre when the trees are from 14 to 18 years of age. The following table gives an itemized account of the cost of growing a 20-acre catalpa plantation and the returns received from it:

Expenditures Per Acre.

Plants, 2722 at $1.15 per thousand	$3.13
Preparation of the ground, planting, cultivation, and pruning,	18.46
Total	$21.59
Interest on $21.59 for 16⅓ years at 5 per cent, compounded	26.34
Cutting and marketing	61.90
Total expense for growing and harvesting the plantation per acre	$109.83

Receipts from the Twenty Acres.

31,397	third-class posts, at 5 cents	$1,569.85
17,349	second-class posts, at 10 cents	1,734.90
4,268	first-class posts, at 12½ cents	533.50
270	first-class posts, at 15 cents	40.50
211	eight-foot posts, at 20 cents	42.20
9	ten-foot posts, at 25 cents	2.25
4	ten-foot posts, at 30 cents	1.20
258	ten-foot posts, at 35 cents	90.30
41	twelve-foot posts, at 40 cents	16.40
167	fourteen- and sixteen-foot poles, at 50 cents	83.50
	Total for posts and poles	$4,114.60
	214 cords of wood, at $5.25	1,123.50
	Total income from twenty acres	$5,238.10

The total of $5238.10, as the proceeds from twenty acres, is equal to $261.90 per acre. If from this the cost of $109.83 per acre for growing and marketing the crop is deducted, we have $152.17 as the net proceeds per acre, equivalent to an annual net income of $9.31 per acre. In other words, if the land had been rented it would have had to bring an annual cash rental of $9.31 per acre for this period to equal the income derived from the plantation.

This plantation was grown on only ordinary farm land, and the returns should be easily duplicated on favorable locations throughout the eastern half of the state.

FINANCIAL ASPECTS.

The woodlot crop, unlike most other farm crops, requires a long period of years to reach maturity. Largely for this reason the importance of the woodlot has been overlooked. Few farmers appreciate the value of a stand of finely formed trees in their woodlot. Such a stand of trees in any woodlot, even though they are saplings, is an asset to the farm, and like a growing colt, represents a definite future value. Unless the waste land found on nearly every farm, that is more suitable for growing timber than any other crop, is utilized in this way, the land will continue to be unproductive for an indefinite time and will be a source of expense and detriment to the remainder of the farm.

The financial success of any woodlot proposition depends upon three factors:

1. *The Initial Cost of the Undertaking.* As growing timber is a long-time investment, the first cost must be held down to a minimum or the interest on the investment will use up the possible profits. The cost of the planting stock is one of the first items to consider. This is a small item when nuts or acorns are to be planted, if a plan has been thought out. In seasons when a heavy crop of nuts or acorns are produced the cost of the seed will be very little indeed, and the planting may be deferred until such a seed year occurs.

When seedling stock is used the plants may be grown in a home nursery or under contract by some commercial nurseryman.[11] The seedlings of the broad-leaved species are easily grown at but very little expense. The evergreen seedlings are more difficult to grow, and it is not advisable to attempt to grow these in a home nursery. Such stock when wanted in large numbers can be contracted for at a much less price than the quoted trade prices.

The cost of the actual planting of the nuts or the seedling trees is also an item of the initial cost. This work must be planned so as to fit in with the regular schedule of the farm work. Plan to begin planting early in the spring before the other work demands full time of the working crew. This work should be organized so that there will be no loss of time when the planting crew is on the ground. In planting trees three

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[11] The state forest nursery will contract and grow seedling stock as cheaply as the farmer can grow it himself.

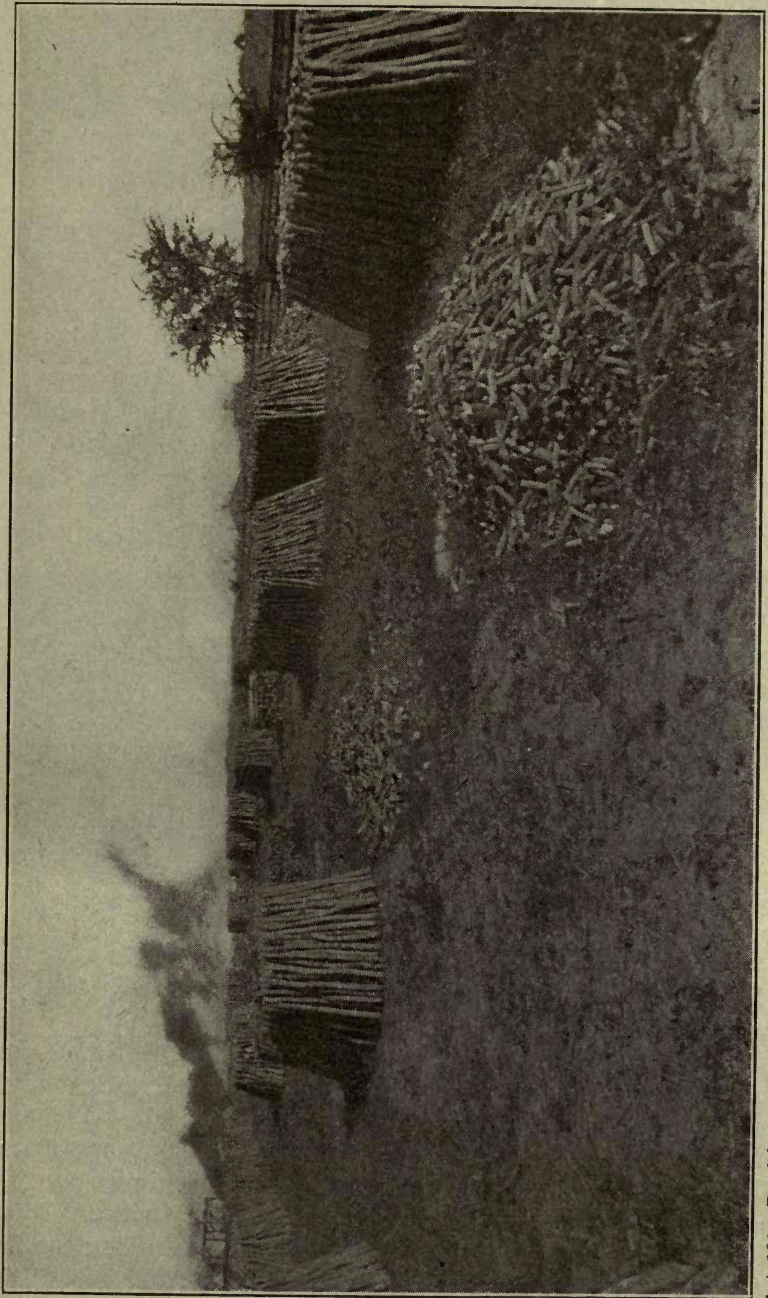

FIG. 181. Partial view of woodlot. Sixty thousand catalpa fence posts and 650 ricks of stove wood, from twenty acres of sixteen-year-old trees.

persons usually work to the best advantage. One man can carry a supply of seedling trees and plant them about as fast as two men can dig holes in which to set them. The tools best suited for the work and the rate at which the holes can be dug will depend altogether upon the character of the soil. A crew of three men should plant from 3000 to 5000 seedlings per day, working eight hours.

2. *The Care of the Growing Crop.* Cultivation and protection is absolutely necessary to insure a successful growth of the young trees, and the cost of this item must also be kept as low as possible; but it is work that must not be neglected or deferred until the weeds have sapped the vigor of the trees. Each year's planting should be limited to the acreage that can be cared for.

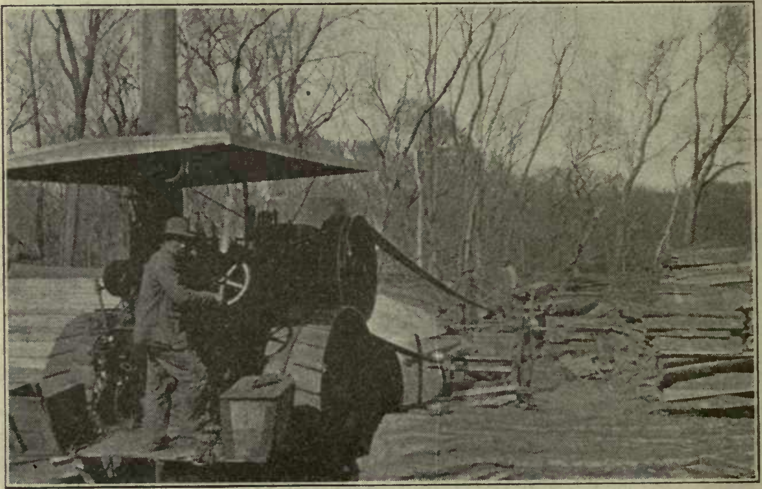

Fig. 182. A portable sawmill. An equipment of this kind will saw from 5000 to 7000 board feet of lumber per day, and it is an economical method of converting logs into useful lumber.

3. *The Harvesting.* This item is chargeable to the final cost and carries no compound interest, but the work must be well planned or it will be an expensive operation. This cost includes the felling of the trees, hauling the logs to market, or the cutting of the logs into lumber, as the case may be. The cutting and hauling will cost from $2 to $6 per thousand board feet, depending upon the length of the haul. Cutting the logs into lumber will cost from $7 to $9 per thousand board feet. The cutting and marketing of the posts and wood may be judged by the figures given for the cost of cutting and market-

ing the catalpa. The posts and wood in this instance were hauled 1½ miles.

Determining the number of board feet in a log is a matter with which few farmers are familiar. This is determined by established rules and practices among lumbermen. These rules and practices vary in different sections of the country and with different species of logs. The Doyle rule is the commonly used rule in this state. The logs should be cut about four inches longer than the even feet to allow trimming off weather-checked or broken ends. In the Doyle log table, which follows, the length of the log is given in feet in the top horizontal line; and the diameter, which is always measured inside the bark at the small end of the log, is given in the left-hand vertical column. The contents of the log in board feet is found at the intersection of these columns. For example, a log is 16 feet long and 22 inches in diameter inside the bark at the small end. By following down the verticle column under 16 until it intersects the horizontal column to the right of 22, we find the number 324. This is the number of board feet of lumber that can be cut from a log of the size given according to the Doyle rule. The number of board feet in a log of any other size can be found in like manner.

Doyle's Log Table.

Diameter in inches.	Length in feet.										
	8	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
10............	18	20	23	25	27	29	32	34	36	38	41
11............	24	28	31	34	37	40	43	46	49	52	55
12............	32	36	40	44	48	52	56	60	64	68	72
13............	40	45	50	55	61	66	71	76	81	86	91
14............	50	56	62	68	75	81	88	94	100	106	112
15............	60	67	75	83	91	99	106	113	121	128	136
16............	72	81	90	99	108	117	126	135	144	153	162
17............	84	95	106	117	127	137	148	158	169	179	190
18............	98	110	122	134	147	159	171	183	196	208	220
19............	112	126	141	154	169	183	197	211	225	239	253
20............	128	144	160	176	192	208	224	240	256	272	288
21............	144	162	181	198	217	235	253	271	289	307	325
22............	162	182	202	223	243	263	283	303	324	344	364
23............	180	203	226	248	271	293	313	336	359	383	406
24............	200	225	250	275	300	325	350	375	400	425	450
25............	220	248	276	302	331	358	386	413	441	468	496
26............	242	272	302	333	363	393	423	453	484	514	544
27............	265	298	330	363	397	430	463	496	530	563	596
28............	288	324	360	396	432	468	504	540	576	612	648
29............	313	351	391	430	469	508	547	586	625	664	703
30............	338	380	422	465	507	549	591	633	676	718	761
31............	365	410	456	502	547	592	638	683	729	774	820
32............	392	441	490	539	588	637	686	735	784	833	882
33............	421	473	526	578	631	684	736	789	842	895	946
34............	450	506	562	619	675	731	787	844	900	956	1012
35............	481	540	601	661	721	781	841	901	961	1021	1081
36............	512	576	640	704	768	832	896	960	1024	1088	1152
37............	545	612	681	749	817	884	953	1021	1089	1157	1225
38............	578	650	723	795	867	939	1011	1083	1156	1228	1300
39............	613	689	765	842	918	996	1072	1149	1225	1302	1379
40............	648	729	810	891	972	1053	1134	1215	1296	1377	1458

EXPERIMENT STATION.

KANSAS STATE
AGRICULTURAL COLLEGE.

Bulletin No. 121—January 1904.

AGRICULTURAL, BOTANICAL AND HORTICULTURAL DEPARTMENTS.

Treatment and Utilization of Flood-damaged Lands.

MANHATTAN, KAN.
1904.

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EXPERIMENT STATION

OF THE

KANSAS STATE AGRICULTURAL COLLEGE,

MANHATTAN.

BULLETIN No. 121—JANUARY 1904.

Agricultural, Botanical and Horticultural Departments.

AGRICULTURAL DEPARTMENT.

A. M. TEN EYCK, B. AGR., Agriculturist.

Renewing Washed and Sanded Lands.

"THE floods of the spring of 1903, by far the most disastrous in the history of the West, covered a territory of more than 2,000,000 acres; they wiped out property approximating $40,000,000, and took nearly a hundred lives."* When the great flood occurred (May 28 to June 5), practically all crops were planted and growing, wheat was headed, and the first crop of alfalfa was ready for the sickle. The waters covered the land for from three to eight days, and on some poorly drained fields remained for weeks, preventing the replanting of the land that season. On well-drained lands, where the water was not deep and remained only two or three days, crops were not usually destroyed. Even alfalfa survived under these conditions. But on all of the lower river bottom, not only were the crops destroyed and great damage occasioned by the loss of farm products, damage to buildings, the washing away of fences, etc., but many fields were permanently damaged by the washing away of soil and the gouging out of great holes by the rushing water. The sand from these washouts and from the washing of the river banks and the cutting of new channels was often deposited over fertile fields further down the stream, so that throughout the valley of the Kansas river and its tributaries considerable areas of land were left covered with white sand from a few inches to several feet in depth.

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* Senator J. R. Burton, in *North American Review*, October 1903.

DEPOSITS OF MUD. Over large areas which were covered with backwater or where the current was slight there was left more or less of a deposit of mud. The covering of mud served to destroy crops which otherwise might have escaped destruction by the water alone, and often because of the sediment or the slow draining and drying of the soil some fields could not be replanted last season. Plate II is an example of such a field upon which a corn crop was destroyed, while plate III shows an alfalfa field which received a deposit of mud from three to twelve inches in depth. The photographs from which these cuts were made were taken July 15, forty days after the waters had receded; yet at this time the land was too wet in many places to drive a team over without miring.

Aside from making more certain the destruction of the crops and perhaps throwing the fields out of use for the season, the deposits of mud are likely to prove beneficial to the land by increasing the fertility and improving the texture of the soil. Where a thick mud covering has been made the land should be plowed deeply, so as to mix the old soil with the new soil and bring some of the old soil up to the surface. The soil bacteria which are considered so essential in fertile soil because of their action in making plant-food available are likely to be more or less lacking in this new deposit, and thus the mixing of the new and the old soil is essential in order to spread them; also, the deep plowing and mixing of the sediment with the coarser soil will tend to improve the texture or physical condition of the soil.

DROWNED LANDS. On low lands and on poorly drained fields stagnant water remained for weeks and even months during the hot summer weather. As these lands are drained and brought under cultivation again the soil will perhaps not produce well for several years. Some of the soluble plant-food has been leached out of these lands. The soil has been settled and puddled, so that it will take some time, assisted by good tillage to reestablish a proper physical condition and good tilth. The bacteria in these soils have perhaps been largely destroyed by the long continued flooding, literally *drowned out,* and it may be several years before they again multiply in such numbers as to maintain the supply of available fertility necessary for a productive soil. A good way to treat such land will be to seed it to grass. The land should be thoroughly drained at once, if this has not been done already. As soon as the surface is in a fit condition disk or plow shallow; later, when the land has become drier, plow deep and leave the soil loose and mellow for a time. If the plowing was done in the fall or winter, grass may be seeded next spring; otherwise it will be better to plow as soon as the soil is in a fit condition in the spring, leave the land fallow during the summer, cultivate with the Acme or disk-harrow occasionally, and seed to grass early in September.

If the land is fairly well drained and not too low, a mixture of orchard-grass, ten pounds, meadow fescue, eight pounds, *Bromus inermis*, six pounds, with one or two pounds of Red clover, per acre, will make a good pasture. For hay, sow three times the quantity named of one of the above grasses, with two pounds of Red clover. A mixture of orchard-grass, *Bromus inermis* and Red clover will often make an excellent hay meadow. On low, wet lands a mixture of redtop, fifteen pounds, and Alsike clover, two pounds, per acre, will make a good meadow or pasture. Alsike clover may also be properly substituted for Red clover with the other grasses on the drier land, and a small amount of *Bromus inermis* and perhaps orchard-grass mixed with the redtop may often prove valuable, especially for pasture, when seeded on the wetter lands.

WASHED LANDS. Where the surface soil was largely removed but no great amount of deep washing occurred, the land may perhaps soonest be reclaimed and made productive by seeding legumes and grasses, but a little different plan should be followed than that described for "mudded" and "drowned" lands. Not only have the bacteria and soluble plant-food been largely removed from washed fields, but the richest part of the soil, containing the humus, has been removed. The subsoil or the subsurface soil remaining is sure to be relatively poor in humus, although the supply of mineral plant-food may be sufficient to produce good crops. Perhaps some of the fertile surface soil remains; at least, the top part of the washed soil will doubtless be richer in humus and contain more plant-food than the deeper soil. Therefore the ground should not be tilled deep, but shallow plowing or even disking the surface will prepare a more suitable seed-bed than deep plowing. The grasses mentioned above as being adapted to fairly well-drained soils, and perhaps alfalfa, can be successfully seeded on washed lands which contained enough available plant-food to start and establish the young plants. The seeding should preferably be done early in the spring.

If the washed land is too poor to start grasses, or if it is desired to continue the use of the land for cultivated crops, it will be necessary to build up the humus of the soil by the application of stable manure, by green manuring, or by the growing of annual legume crops. A good coating of well-rotted manure disked into the ground will much improve the seed-bed for the planting of legumes and grasses and other crops. If no stable manure is at hand, the field may be prepared by shallow plowing or disking early in the spring and given a light seeding of oats, barley, or emmer. This crop should be plowed under rather shallow for green manure, about the last of May, and the ground subsurface-packed if possible, or at least well tilled with a harrow, disk, or Acme harrow, and reseeded with cow-peas, planted in close drills or sown broadcast, at the rate of four to six pecks per acre. The cow-peas may be cut for hay if they make a rank growth, or, better, the crop should be plowed under before it becomes too rank and mature, and the land immediately reseeded to oats, which should be left as a cover crop during the winter. This land may now be in a fair condition to grow a crop of corn or seed down to grass, or the green manuring may be repeated again the next season, as the judgment of the farmer may direct.

For badly washed areas in which the top soil has all been carried away and the surface has been left rough and broken, as shown in plates IV, V, and VI, little can be done.

After a few years the soil of such areas will become weathered and more fertile, when, by scattering grass seeds, they may be turned into pastures.

SANDED AREAS. The sanded lands are the most extensive and perhaps the hardest to reclaim. Some of the land replanted last season was covered with a light coat of sand. Where the layer of sand was not so thick but that the lister placed the corn in fertile soil beneath the sand a good crop was secured. The cultivation during the season mixed the sand with the good soil, and little trouble is likely to be caused by the sand where the depth of the deposit did not exceed two or three inches. Deep plowing on such fields will more thoroughly mix the sand with the soil and give a more uniform texture and better tilth.

The problem of how to get rid of the sand is a difficult one on those fields in which the covering is six inches to several feet in depth. The sand was often left more or less in drifts by the water, and during the summer the conditions have been made much worse by the winds. When the sand is not more than six or eight inches deep, it may be possible to turn it under and bring up the good soil by plowing very deep. With a strong sixteen- or eighteen-inch plow, four to six horses ought to turn a furrow ten to twelve inches deep. If a plow could be constructed with a larger, longer mold-board than the ordinary plow, capable of elevating the earth twelve to eighteen inches high, it might be used to deepen the furrow of the ordinary plow. It would be possible also to construct a gang so that one plow, with a high mold-board, set at a lower level, will follow the other plow in the same furrow; but with the ordinary plow it is not practicable to attempt to plow more than one furrow deep, as the earth cannot be elevated, and will simply fall back to the bottom of the furrow, which will be left mellower but little deeper than it was by one plowing.

It may be profitable, on valuable land and on small fields, to use the spade with the plow, and by digging trenches, bury the sand and bring the good soil to the surface. In some instances where the sand lies in deep drifts it may be practicable to haul it off the field with scrapers or pile it up in large mounds.

When the sand is buried or mixed with the soil, the question arises as to the effect which it may have on the texture and fertility of the soil and in the production of crops. The effect which the sand has on the soil texture will depend upon the character of the soil and the coarseness of the sand. If the original soil was heavy and compact, a light dressing of sand may improve the texture and increase the available fertility, but if the soil was already sandy, the addition of more sand will tend to reduce the fertility and produce a coarser and more open texture, unfavorable to the holding of soil moisture and to the root growth of plants.

To improve the physical condition of the soil and prepare a proper seed-bed, such fields should be thoroughly firmed and packed by the use of a subsurface packer or similar tool; but even with thorough preparation lands in which the sand has been buried or mixed with the soil by deep tillage are not in a condition to seed at once to grass, but had better be planted with corn or other cultivated crops for a few seasons, or the system of green manuring described under "Washed Lands" may be profitably employed, especially if the soil is light, and lacking in humus. When land has been plowed very deep and the subsoil has been brought to the surface, the land is not likely to produce well the first season, because the raw soil must weather and decay and the bacterial growth must be reestablished before a sufficient supply of plant-food can be made available to meet the requirements of the crop.

In case the covering of sand is too deep and too extensive to be subject to any of the methods of treatment suggested, it may be practicable to hold the sand and attempt to hasten the building of it into soil by means of soil-binding grasses and legumes, discussed in another part of this bulletin, or doubtless in some cases it may be more profitable to leave nature undisturbed in her sturdy efforts to renew the soil and replant the sanded wastes.

SEED TO GRASS LANDS WHICH ARE APT TO WASH. Perhaps the greatest permanent damage to farms resulting from the flood was caused by the washing away of the soil. Thousands of tons of fertile valley soil were swept away from many fields. Some of this soil was deposited again on other fields, but much of the fine sediment and all of the soluble plant-food was swept into the Missouri and thence onward to the sea. The sanding was also the direct result of washing.

It was observed that the cultivated fields were the ones which were cut up by the water, while lands which were in grass and alfalfa were not usually damaged by washing. Grass or alfalfa served as a protection to the land, and although the crop itself may have been destroyed, the loss of the crop was small compared to the protection afforded by the crop to the soil.

Only a small fraction of the land in the valleys damaged by the flood was seeded to grass or alfalfa and often the fields were tilled and planted with annual crops almost to the river's edge. A large part of the low-lying land in the river bends and bordering the river might profitably be kept in grasses or alfalfa much of the time, thus insuring protection to the soil in case floods should again occur.

CROPS AFTER THE FLOOD. Plate XIII shows a field of sorghum cut for fodder on the farm of Mr. Fred Moehlman, in Moehlman bottom, south of Manhattan. This field was planted about July 20. Corn planted after the flood made an excellent growth of stalks and usually matured a good crop of ears. Many fields of Kafir-corn also matured seed, while sufficient sorghum and Kafir-fodder was produced throughout the flooded districts to provide roughage for wintering the stock.

BOTANICAL DEPARTMENT.

H. F. ROBERTS, M. S., Botanist.

Sand-binding Grasses.

One important matter to consider, for owners of sanded lands which are too deeply covered to be successfully handled in an agricultural way, and in which an accumulation of humus is an essential preliminary to its subsequent use for agricultural purposes, is the introduction of what are known as sand-binding grasses. A grass, to be a "sand-binder," must be, first, a perennial, and must have the habit either of sending out creeping stems below the ground, from which the aerial shoots come up, or of sending out runners above the surface of the ground, or both. As a matter of fact, the true "sand-binders" spread prevailingly by underground stems or rootstocks. By this means the plant secures for itself greater protection against drought and the scorching heat that often prevail in summer-time on the immediate surface of sanded areas. The buffalo-grass, although it sends out runners which in the course of a single season will extend from a foot to a foot and one-half out from every side of the parent plant, is not adapted to sandy regions, and is not available therefore for the present purpose. It must further be remembered by farmers, that if they undertake to plant sanded land with sand-binding grasses, it must not be done primarily with an idea of getting immediate financial returns from the grasses themselves. While there are some sand-grasses, such as the sand blue-grass, that are available for hay, most of them have such tough and wiry stems and such hard, coarse leaves that they are not at all adapted to hay purposes, and others, such as the one above referred to, are not in the market. It is also the case that sand-grasses do not commonly form a close turf on the soil, but cover it in rather loose and open fashion, which of course means a small yield of hay per acre.

The real value of sand-binding grasses lies not in what they may yield of themselves for pasture or forage, but in their ability to hold the sand in position and keep it from drifting, and to lay the foundation for an agricultural soil by the accumulation of humus. While there are a number of species of sand-grasses, there are comparatively few, the seeds of which are a commercial article. Foremost among these should be placed the beach-grass or marram grass, *Ammophila* *arenaria* (L.) Link, commonly sold as *Ammophila arundinacea.* This is a perennial grass, spreading by underground stems, growing from two to four feet high, with long, coarse leaves and a narrow, spike-like flowering head from five to six inches long. This grass is extensively found on the sandy seacoast region of the Atlantic, as far south as Virginia, and is also the common grass found covering the sand dunes along the Great Lakes, notably on the eastern coast of Lake Michigan. It is of no fodder value. Its seed runs in weight fifteen pounds to the bushel and sells at about forty-five cents per pound, or 100 pounds for about $40. The seed should be sown in the spring, either drilled or harrowed in, and the ground covered with brush to hold the seed in place until the young plants have gained a start. The usual method is to transplant already established sods, and by this means large areas of dune and beach land have been planted in Europe and along the eastern coast of the United States; but inasmuch as *Ammophila* is not likely to be found accessible already established, it will be necessary to start an area of young plants as above indicated, for further transplanting.

Next, perhaps, to *Ammophila arenaria*, among those grasses the seed of which is commercially available, is *Poa compressa* L., the Canada blue-grass. This is a small perennial grass, with slender, wiry, flattened stems, growing from six inches to one and one-half feet high, and found in waste places generally, scattered over the northern United States. It also propagates by underground stems, and does well on the poorest soils. Unlike the *Ammophila*, it is a valuable pasture grass, and if once well established it will prove of some worth in itself, beside being, in addition, very valuable as a sand-binder. It is, however, not likely that it will take hold at the outset in loose sand as readily as the beach-grass. It is therefore recommended that beach-grass be used first to fix the soil before the other is sown.

The two grasses above given are the only ones which this department feels absolutely justified, from observation and experience, in recommending for immediate use. There are a few others among the fescue grasses, such as Hard fescue (*Festuca duriuscula*), Sheep fescue (*Festuca ovina*), Red fescue (*Festuca rubra*), and Slender fescue (*Festuca tenuifolia*), and lime-grass (*Elymus arenarius*), which may or may not prove valuable here, in connection with the Canada blue-grass, and it is planned to use them during during the coming season in an experimental way on sanded lands in this vicinity.

In connection with the grasses, it is desirable, as soon as possible, to start legume plants of species which will endure hard conditions. The sanded lands, being notably deficient in humus at the surface, and consequently in compounds of nitrogen, so essential as plant food, it is especially desirable to introduce those plants which are known to be nitrogen gatherers. The legume family, including such common and well-known plants as alfalfa and the clovers, represent this family; but neither alfalfa nor the common clovers will make a "catch" in very loose, sandy ground. The sand vetch (*Vicia villosa*) is a biennial legume which cannot be too highly praised as a nitrogen gatherer. It does well on poor, sandy soils, forms a cover of thick, matted stems a foot or so high, and self-seeds liberally. It is recommended that sand vetch be sown next spring, mixed with rye, at the rate of one bushel to the acre. The price varies according to the market, but fifteen cents per pound may be taken as a fair average price.

If the vetch and rye mixture be started first, it may then be possible to sow Canada blue-grass broadcast, in the fall.

HORTICULTURAL DEPARTMENT.

ALBERT DICKENS, M. S., Horticulturist.

Trees for the Sanded Areas.

In making plans for utilizing land which has been damaged by floods, the forest-trees deserve careful consideration. There is little question as to the success of trees in such locations, and but little as to their ultimate value. Land that is so badly sanded as to require manuring before it contains sufficient humus to support crops of grass and grain will support some species of trees. One great advantage in planting such soil to trees is that when once started the danger of blowing is obviated. In growing grain or fodder crops upon such land, there must be for many years the danger of its blowing badly, which is certain to injure its value very considerably. The particles of organic matter in various stages of decomposition are, when partially dry, very light, and certain to be blown away if exposed to the wind. Experience in farming sandy land has taught that severe blowing reduces fertility to a very marked extent. In planning for the use of such land, the factor of certainty is much greater with tree crops than with annual crops. Practically all of the flooded land is so low that tree roots will reach the strata of constant moisture in a very short time, which in itself insures certain, and, in most cases, rapid growth. The protection of the land from blowing is one of the necessary factors in improving it, and trees will do this more certainly than any other crop.

In many cases, where a deep deposit of sand has been made, there is danger of the land being badly washed by high water. A volume of water which would have occasioned little damage prior to the great flood of last year would now probably cause considerable washing of the banks, and a growth of trees along and near the bank would to some extent lessen this danger.

The principal objection to planting forest-trees as a crop is that considerable time must elapse before any part of the crop can be marketed. In the case of the flooded areas, this objection is certainly less forceful than in case of good farm lands, for, with much of it, any crop secured will be a light one and return at best but small profits. In view of the facts that flooded lands must be carefully handled in order to improve their texture and fertility, and that considerable time must elapse before they can be expected to return even a fair profit, and as the success of trees in similar locations and conditions is a matter of common observation, it seems probable that in many instances the growing of trees is the best use for such land.

The selection of species for planting is a matter of importance, for though all trees are good, some are much better than others and more valuable, but as a rule the more valuable are slower to reach marketable size. Post production may be regarded as giving the quickest returns from forest-tree plantations, and catalpa (*Catalpa speciosa*) and Black locust (*Robinia pseudacacia*) may be expected to produce good posts in less time than any other trees grown in our climate. These species, however, succeed best in fairly rich soil and would be better adapted to locations where good soil has been covered with sand than to deep deposits of sand. The locust borer, *Cyllene robiniæ*, works such havoc in Black-locust plantings as to almost exclude Black locust from the list.

The Osage orange (*Toxylon pomiferum*) is rather slower in growth, but furnishes posts which in most localities bring the highest price. It seems to be similar to the catalpa in soil requirements. The Russian mulberry (*Morus alba*) is another post tree, probably ranking next to catalpa in rate of growth, but requiring more care to produce marketable posts. The length of time required to produce marketable posts varies with conditions, season, and soil, a good average probably being—catalpa eight years; mulberry, ten years; Osage, twelve years. All renew readily from coppice growth, and in each case the second growth furnishes posts in less time than the first.

Whenever trees planted for posts make but poor growth during the first season or two it is good practice to cut them back to the ground, which nearly always results in a strong growth. On land that is deeply covered with sand it is probable that the more-rapid-growing trees will give better results. The cottonwood (*Populus deltoides* or *P. monolifera*) is believed to be the best tree of this class. Young trees are easily secured from cuttings or natural seed-beds along the rivers, and transplant very readily. Many tracts of the flooded land are now thickly covered with young cottonwood trees. The seed was ripe soon after the flood, and the wet sand and soil provided the best of seed-beds. In most cases good growth was made during the summer. Plate XIV shows a tract that seemed to be bare sand when the waters receded early in June. The young trees, mostly cottonwood, with an occasional willow, stand very thickly, and made growth varying from two to seven feet, averaging probably between four and five feet. Plate XV shows a clump of these young trees. Where the land has been planted by natural means, it is questionable if any better use can be made of such land than to allow the trees to stand. Within a few years the stronger trees will outgrow the others, thinning will take place naturally, the land being, indeed, natural forest land. A great deal might be done in such plantings by thinning the trees, giving the stronger a better chance to develop. In five or six years the poles would more than pay for the thinning.

Plate XVI shows a growth of cottonwood on a bank of the Kansas river. The present owner of the land states that when he bought the property, about fifteen years ago, it was a thicket of young trees, probably five or six years old. Examination of the trees recently cut shows twenty annual rings. The trees vary considerably in height and diameter, some of the largest, those near the edge of the grove, measuring slightly over 100 feet in height, twenty-four inches in diameter at the ground, and eighteen inches twenty feet from the ground. What was considered an average tree was cut November 5, showing twenty annual rings and measuring seventy-five feet in height, seventeen and one-half inches in diameter at the ground, and fourteen inches at nineteen feet, where it branched, and containing about twenty-five cubic feet of cord-wood in the top and limbs. Many of these trees will now make fair logs for sawing, and if left standing will increase in size for a number of years.

The demand for low-grade lumber suitable for packing cases, apple and potato barrels is growing. The average of prices obtained from dealers is twenty-two dollars per thousand for selected stock, sixteen dollars per thousand at the mill, ten dollars per thousand on the stump. The following prices obtained December, 1903, from S. N. Higinbotham, dealer in wood, shows the market value of cottonwood compared with other species: Cottonwood, $3; red elm, $4; hackberry, $5; maple (soft), $3; walnut, $4; oak, $5; box-elder, $3; hickory, $5. It would seem that at such prices for timber and fuel, the cottonwood is not to be despised. Where land is to be planted, it is advisable to plant cuttings from the trees of strong, straight growth.

The Carolina poplar (*Populus deltoides*, var. *carolinensis*) has not been so long or so widely grown, but seems to be hardy, equal to the best cottonwoods in vigor, and more uniform in growth. It grows very readily from cuttings. The results of plantings of these and other species of trees are recorded in Experiment Station Bulletin No. 120.

Explanation of Illustrations.

Plate I. The flood at its height, looking east from Bluemont, north of Manhattan, across the valley of the Big Blue, and down the valley of the Kansas. The pumping station of the city water-works, the Blue Valley branch of the Union Pacific railroad, and the channel of the Blue river, with a strip of timber on the east bank, are shown in the foreground, while beyond is a broad expanse of water as far as the eye can see. The channel of the Kansas river lies in the background to the right, the hills to the left, across the valley of the Big Blue, are about six miles distant.

Plate II. A quarter-section of land on the farm of Fred Moehlman, in Moehlman bottom, south of Manhattan. A crop of corn on this field was destroyed by the flood, and on July 15, when this picture was taken, the field was too wet to cultivate, and some of it was still under water.

Plate III. An alfalfa field on the farm of Chas. Rosencutter, in Moehlman bottom. This field was covered with a deposit of mud from three to twelve inches in depth, and the alfalfa was totally destroyed. The ground was too wet to plow on July 15, and no crop was grown on the field last season.

Plate IV. A washed area on the farm of John Dempsey, one and one-half miles east of Manhattan, showing soil removed and the field badly cut up by the water. This particular washout covered about four and one-half acres in the middle of a cultivated field.

Plate V. A nearer view of a portion of the above washed area, which gives a better idea of the washout. The pit shown was more that ten feet deep.

Plate VI. On the farms of James Allingham, Wm. Allingham, and Mrs. Martha Finley, in Allingham bend, south of Manhattan, some sixty acres were destroyed by the washing. Plate VI shows one of these washouts, which was about 100 yards wide, 400 yards long, and 20 feet deep at its greatest depth.

Plate VII. This is a view of the new channel of the Kansas river which was cut across Allingham bend, south of Manhattan, during the flood. The new channel crosses the farms of the parties mentioned above, also the farm of Mrs. Emma H. Bowen. This channel is 40 to 130 rods wide and over a mile in length. The body of water to the right is the old bed of the river.

Plate VIII. After the flood—on the farm of Harry Deibler, east of Manhattan, The clump of trees to the west is what remained of a fine young orchard. Before the flood the house now seen in the distance stood in the edge of the orchard. The debris is largely ties and steel rails, the remains of the Rock Island railroad, which bordered the farm on the south.

Plate IX. A sanded area of about ninety acres, on the farm of Gus Carlson, in Moehlman bottom. The sand was several feet deep in places, and was beginning to blow and drift about with the wind. This view was taken July 15. A scant vegetation was struggling up in places where the sand deposit was shallow, and over a part of the area a thick growth of young cottonwoods was starting. Hundreds of acres of this once fertile and beautiful valley were rendered useless by this covering of sand.

Plate X. A sanded area of about sixty acres, on the farm of G. E. Spohr, also in the Moehlman bottom. The man standing in the excavation is Mr. Spohr, who, by digging at different points, estimated the depth of the sand on this area to vary from one to five feet.

Plate XI. An orchard which was destroyed by the flood, on Mr. G. E. Spohr's farm. In this orchard of twenty-three acres, some thirteen acres of trees were washed down, covered with sand and debris, and destroyed.

Plate XII. A bur-oak stump on the roadside, east of Manhattan, showing how the soil was washed from the roots by the forming of eddies in the current. Many trees in orchards and groves and along the river banks were washed out or injured in this manner.

Plate XIII. A crop grown after the flood. A field of sorghum, on the farm of Fred Moehlman, in Moehlman bottom. This was planted July 20 and made an excellent crop of fodder.

Plate XIV. A tract of land that seemed to be bare sand when the waters receded, early in June, but in November was thickly covered with cottonwoods and willows.

Plate XV. Clump of young cottonwoods that have grown up on land flooded in June.

Plate XVI. A growth of cottonwoods about twenty years old, on the bank of the Kansas river.

ACKNOWLEDGMENT.

The photographs from which the cuts shown in this bulletin were made were taken by Dr. S. C. Orr, of Manhattan, who does much work of this character for the Agricultural College and Experiment Station, and spares no effort to produce the best possible results.

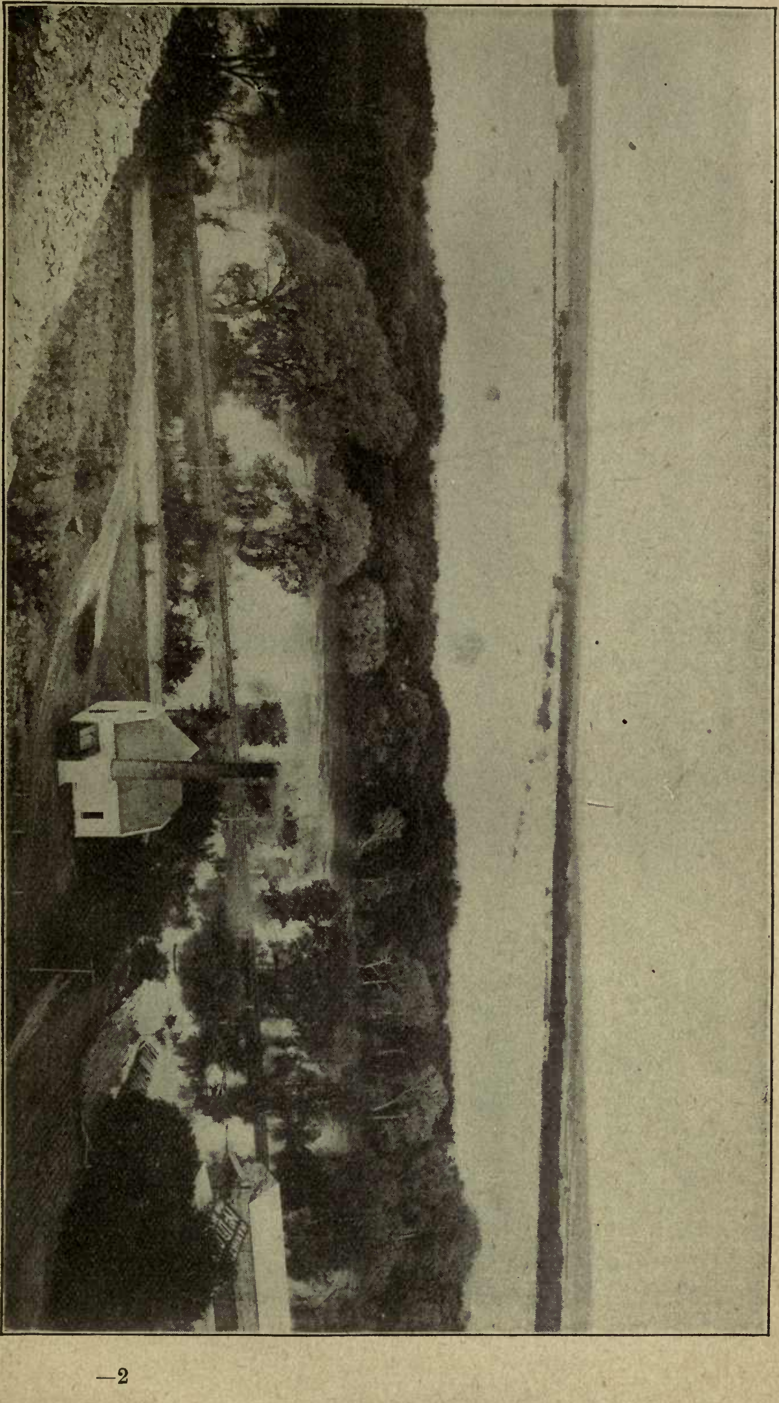

Plate I.—The flood at its height. Looking east from Manhattan.

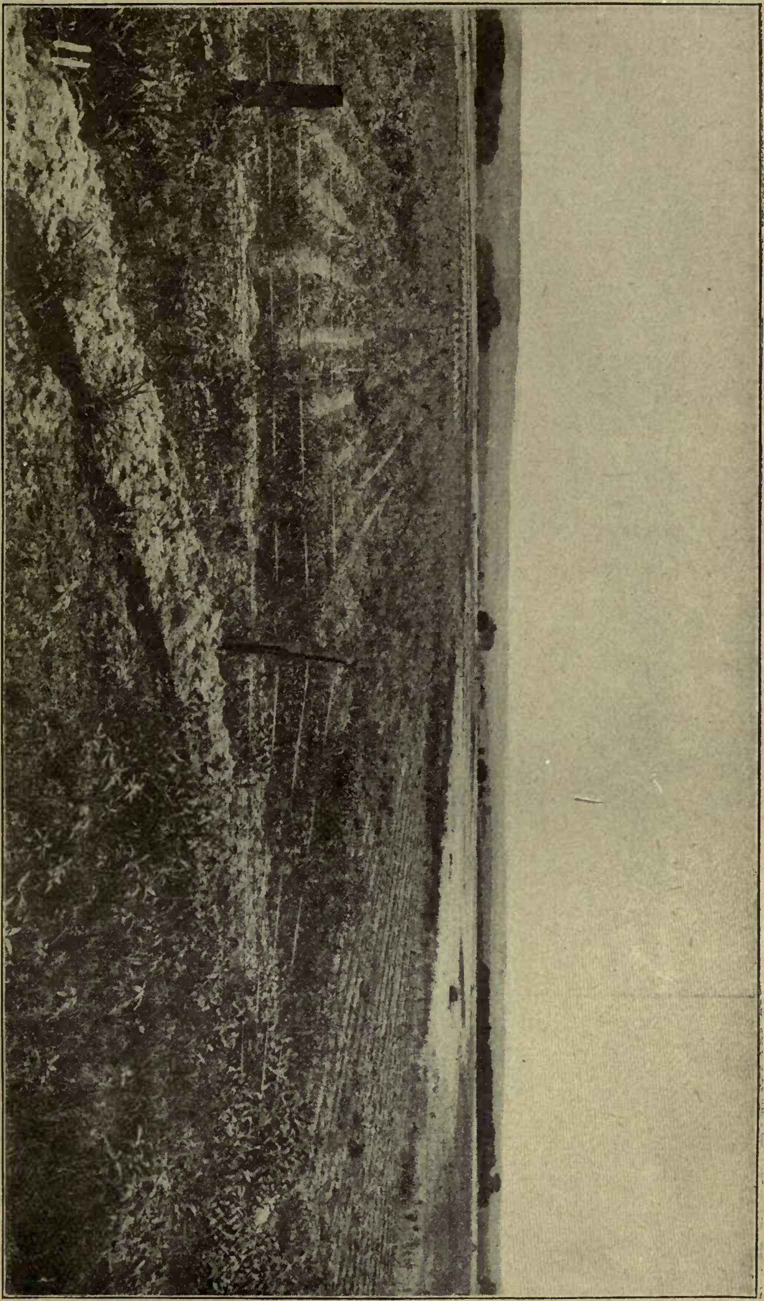

Plate II.—A corn crop destroyed and ground still too wet to plant, forty days after the flood.

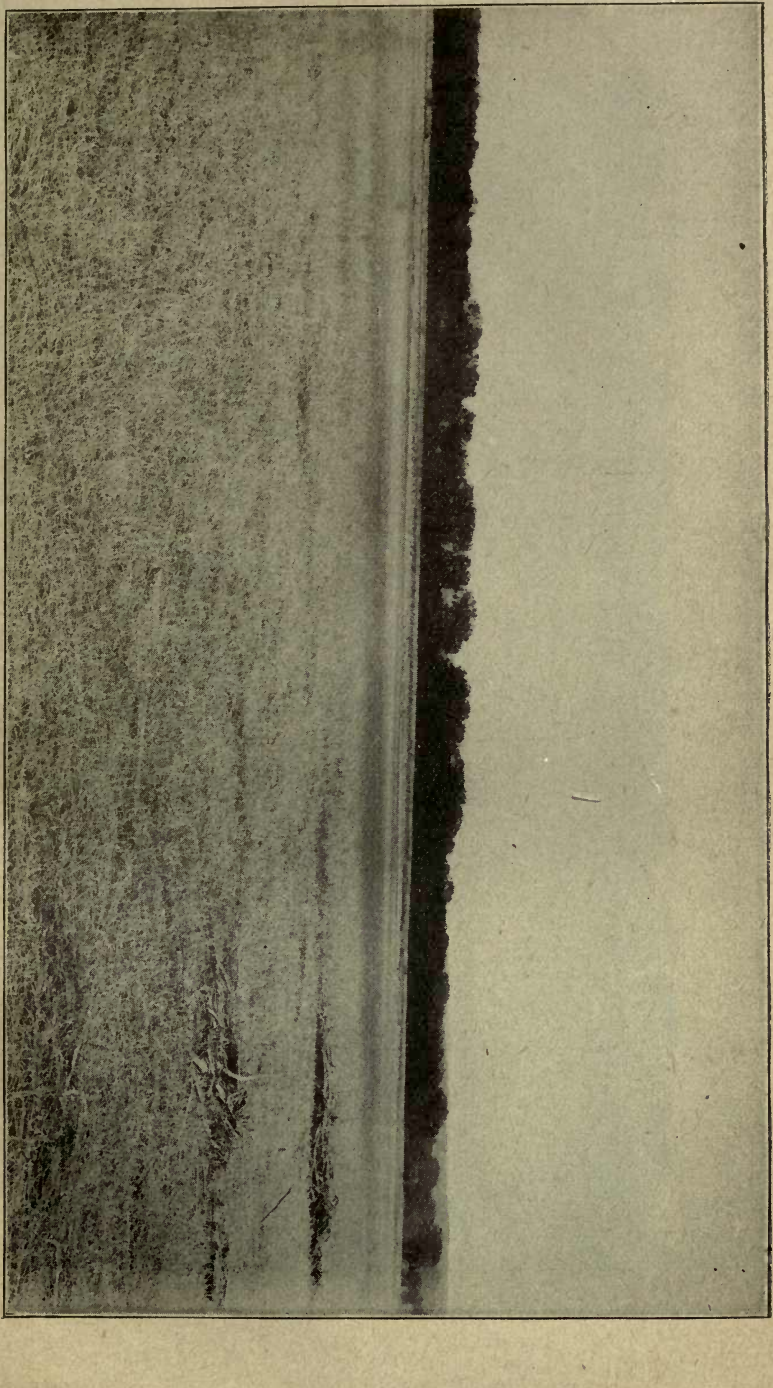

Plate III.—An alfalfa field covered with a deposit of mud three to twelve inches thick.

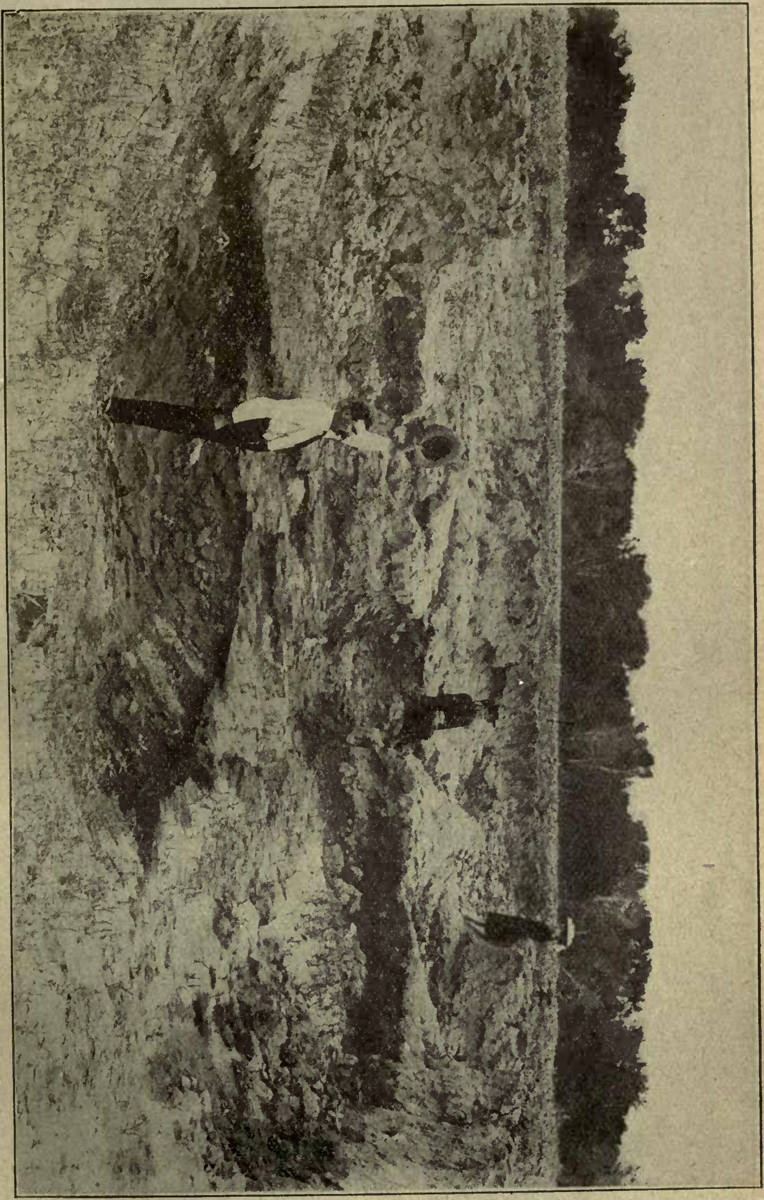

Plate V.—Showing the depth of excavations.

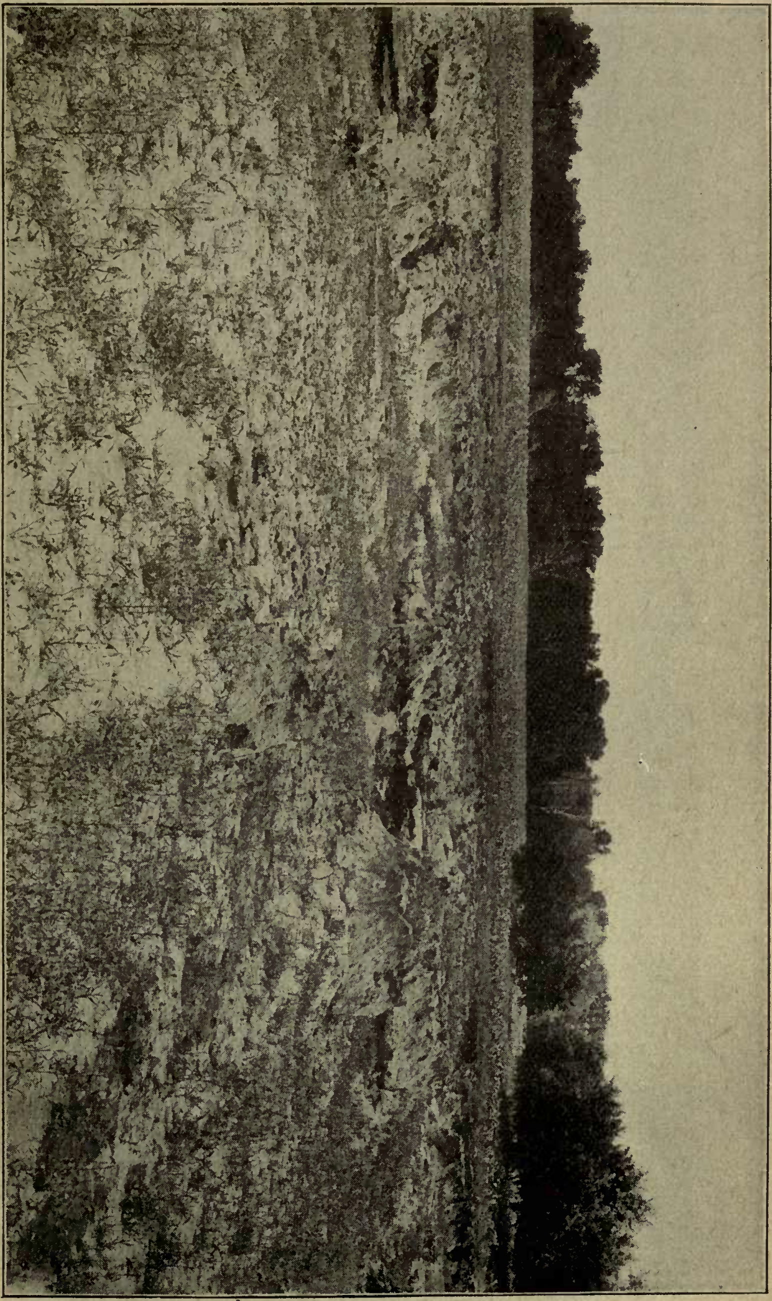

Plate IV.—A washed area; before the flood a level, cultivated field.

Plate VI.—A big washout. This hole was more than an acre in area and twenty feet deep.

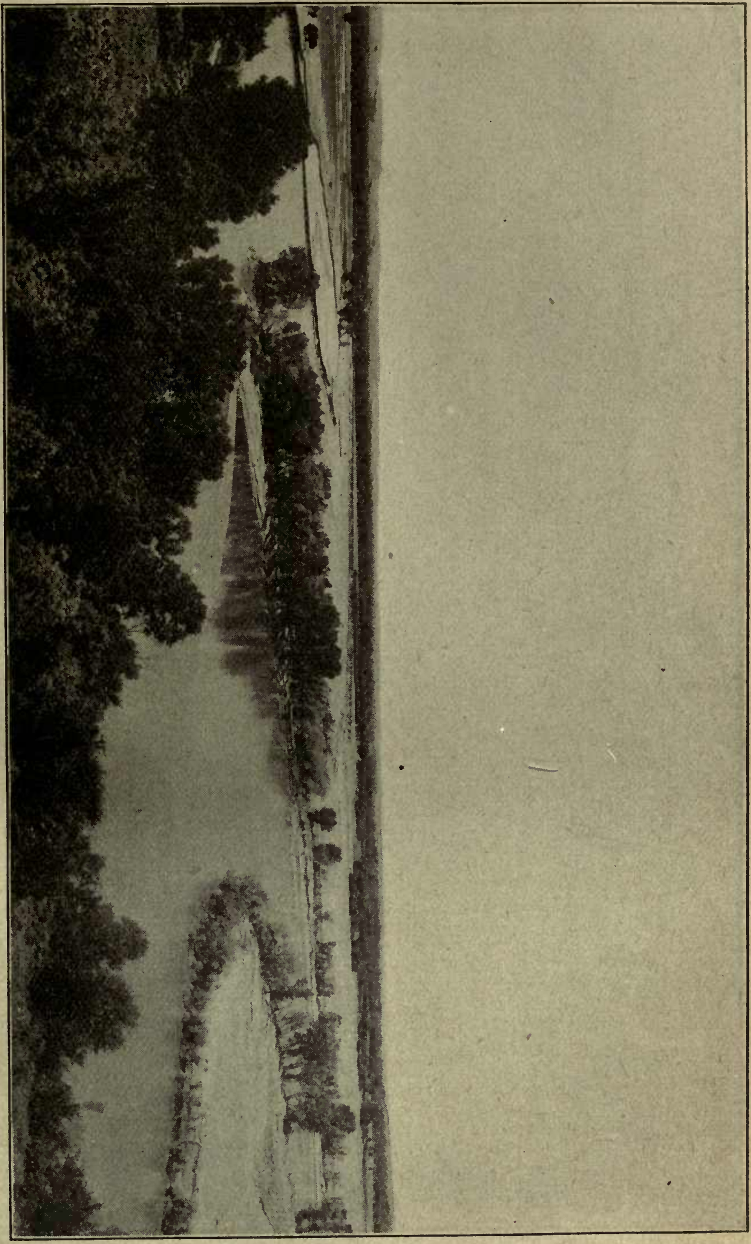

Plate VII.—The new channel of the Kansas river, across Allingham bend, near Manhattan.

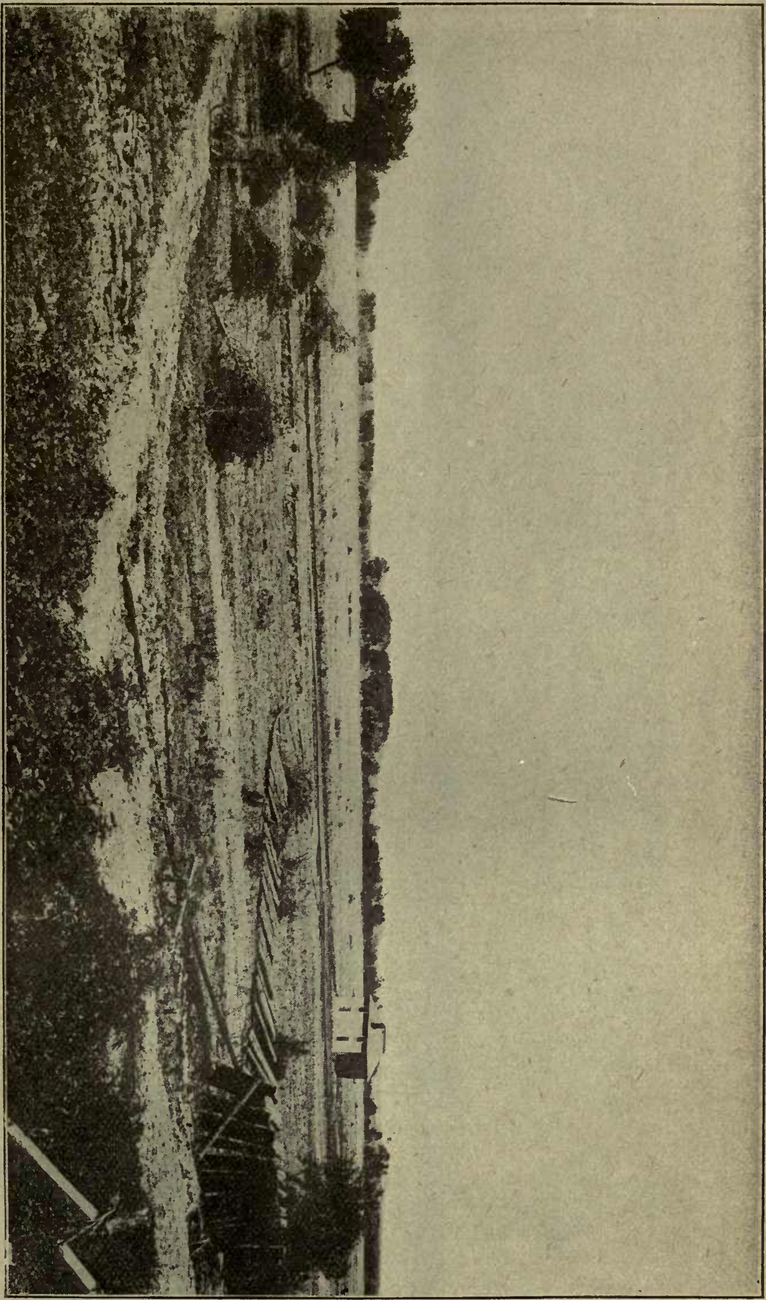

Plate VIII.—After the flood—on the farm of Harry Deibler, east of Manhattan.

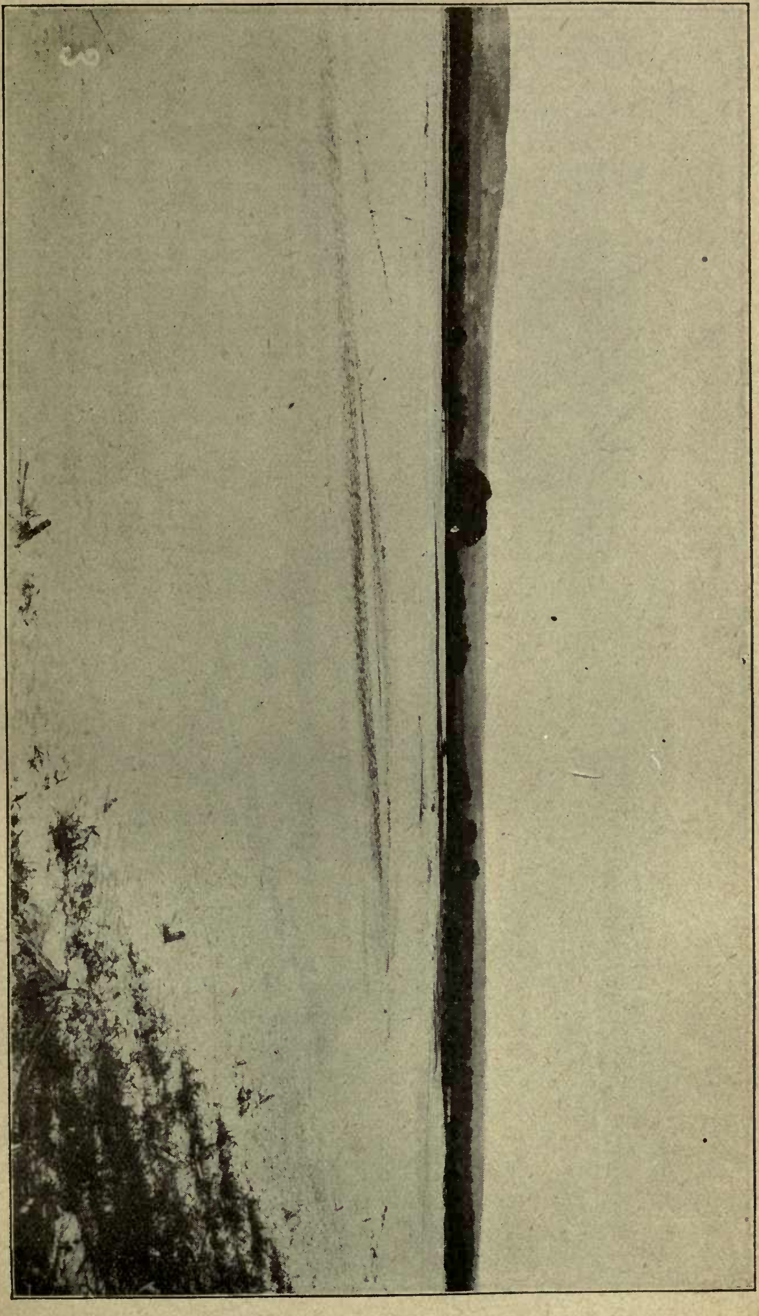

Plate IX.—Ninety acres of once fertile farming land covered with sand.

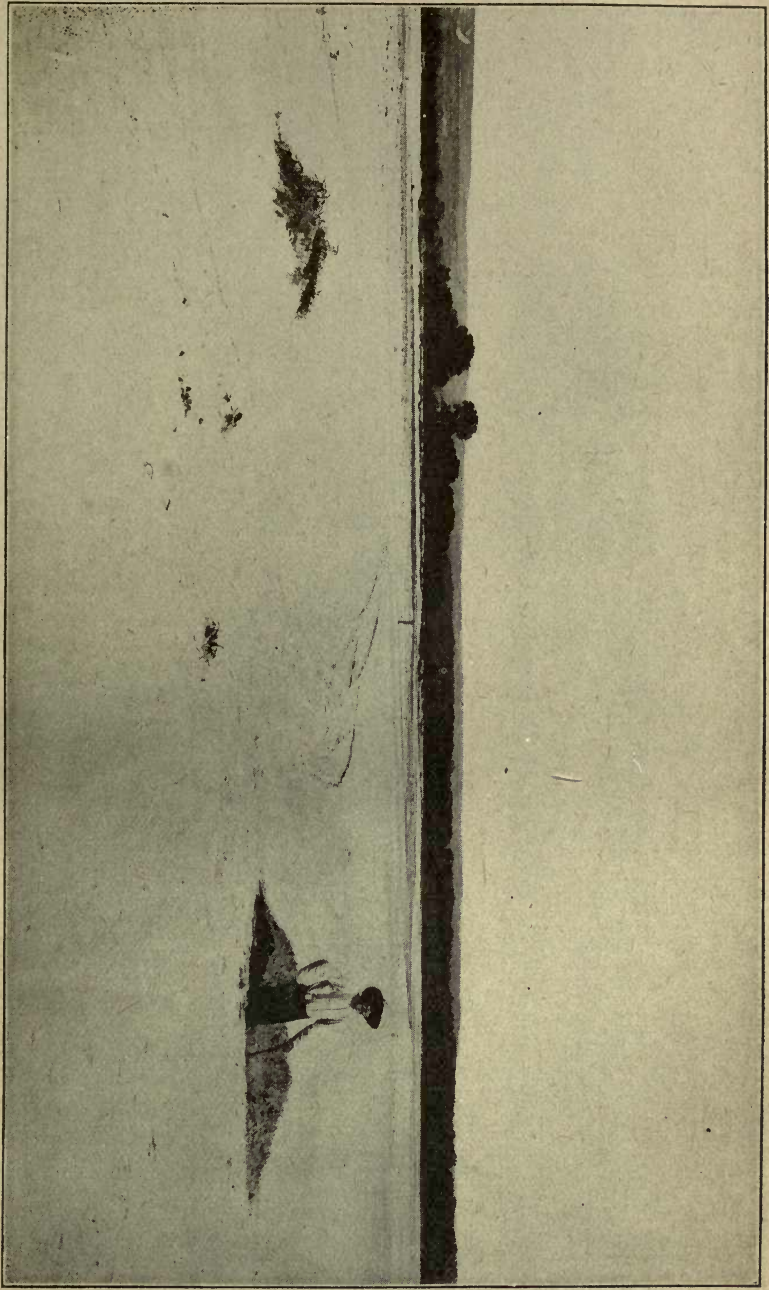

Plate X.—A sixty-acre field covered with a coat of sand one to five feet in depth.

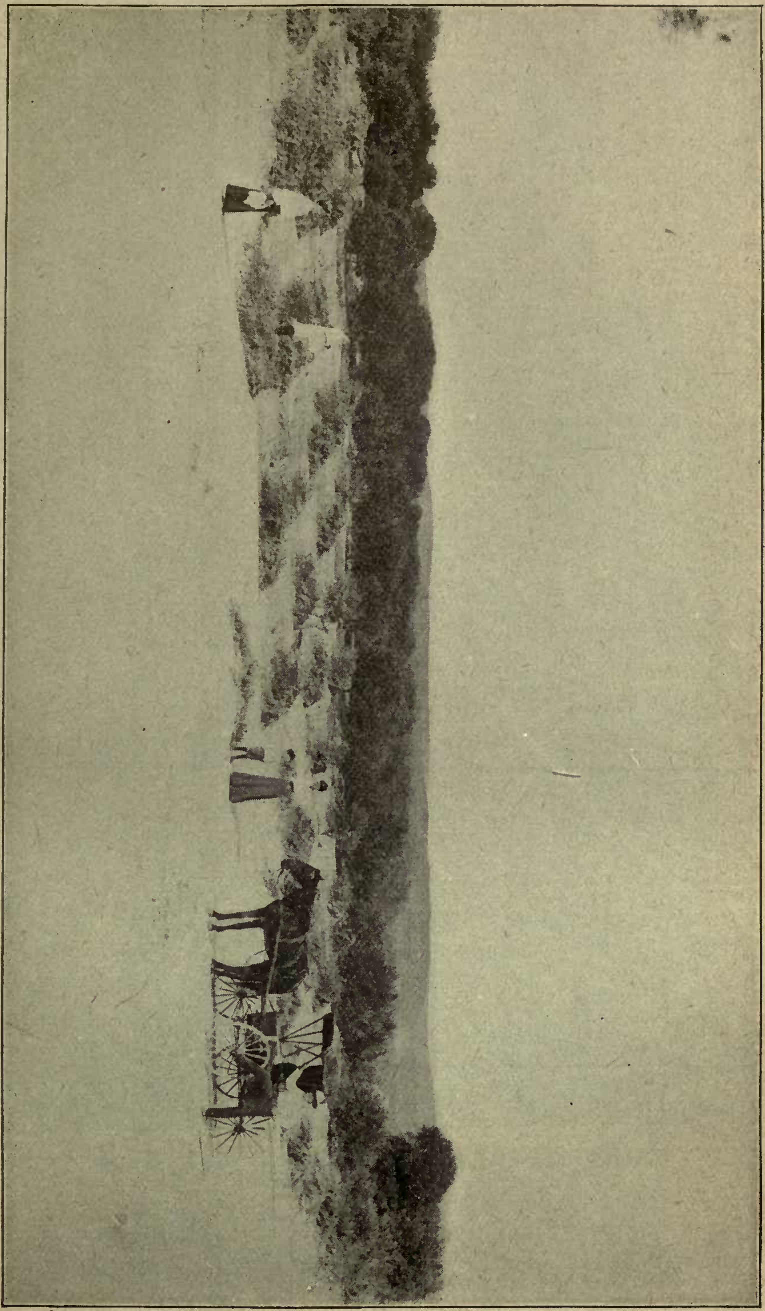

Plate XI.—Mr. G. E. Spohr's apple orchard after the flood.

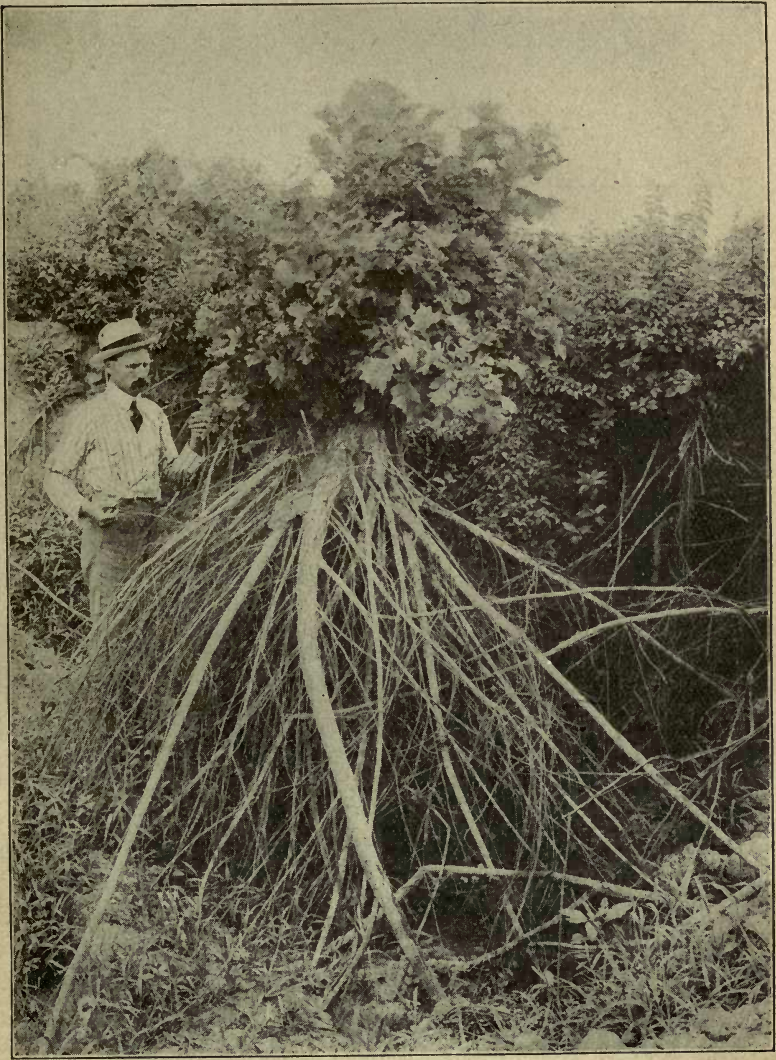

Plate XII.—A bur-oak stump, as left by the water.

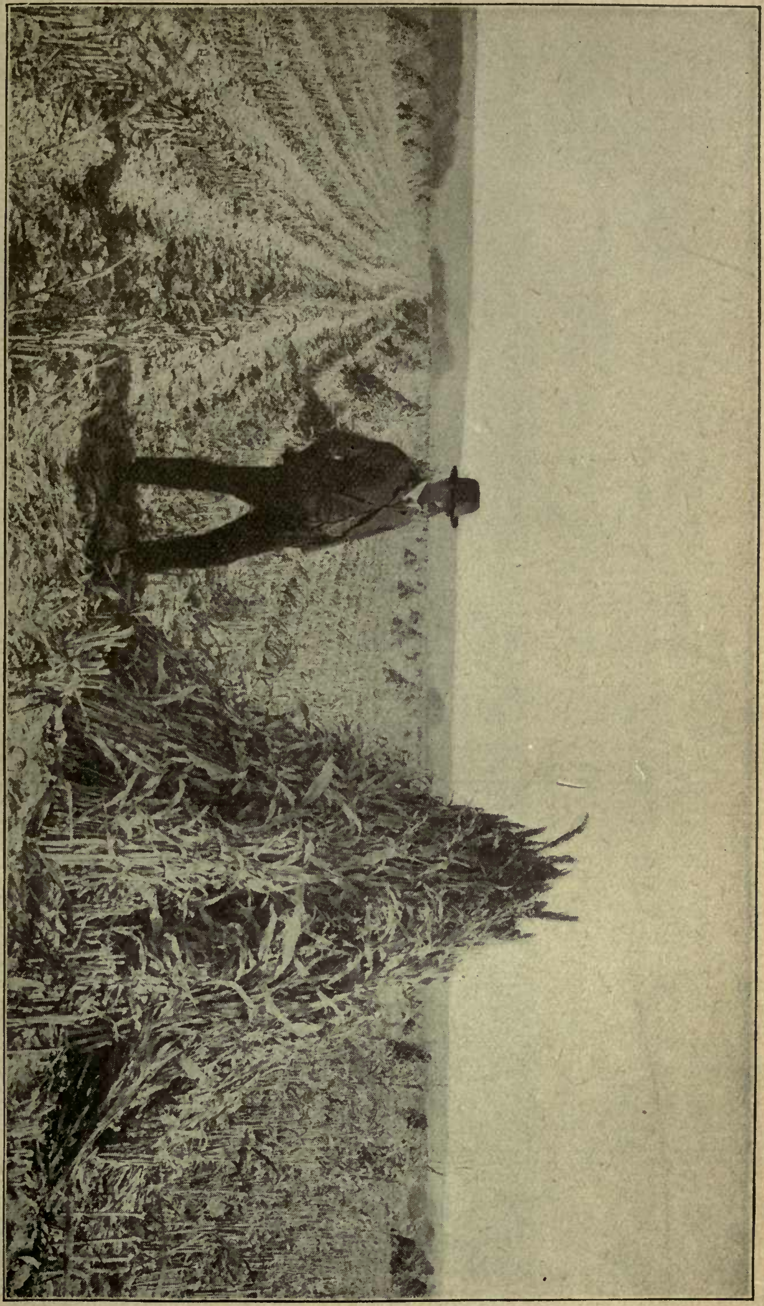

Plate XIII.—A crop of sorghum grown after the flood.

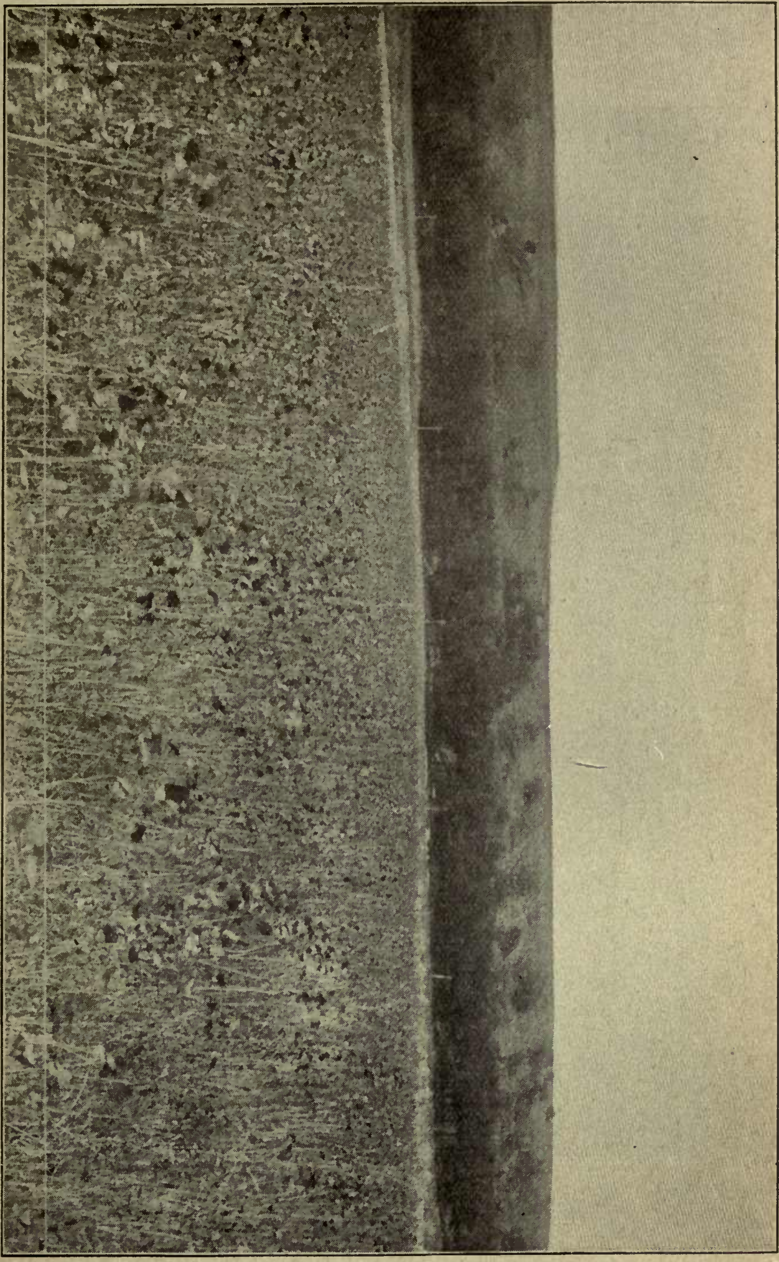

Plate XIV.—Growth of young cottonwoods on land flooded in June, 1903. Photograph taken November, 1903.

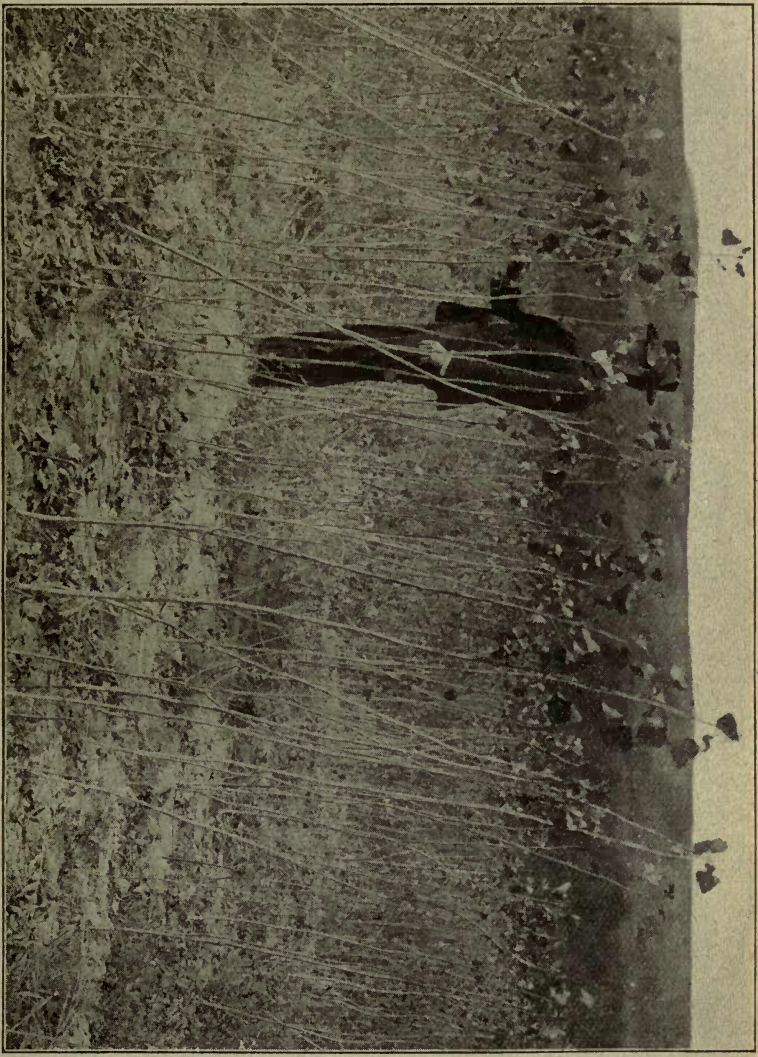

Plate XV.—Clump of cottonwoods on land flooded in June, 1903. Photograph taken November, 1903.

Plate XVI.—Grove of cottonwoods on Kansas river bank, about twenty years old.

Bulletins of the Station.

Those marked (*) are out of print.

*No. 1	April, 1888	Organization, Equipment, and Aims.
*No. 2	April, 1888	Experience with Cultivated Grasses and Clovers.
*No. 3	June, 1888	Life-history of Two Orchard Pests.
*No. 4	September, 1888	Experiments with Wheat.
*No. 5	December, 1888	Sorghum, and Sorghum Blight.
*No. 6	July, 1889	Silos and Ensilage.
*No. 7	July, 1889	Experiments with Wheat.
*No. 8	October, 1889	Preliminary Report on Smut in Oats.
*No. 9	December, 1889	Experiment in Pig Feeding.
*No. 10	May, 1890	Notes on Conifers for Kansas Planters.
No. 11	July, 1890	Experiments with Wheat.
No. 12	August, 1890	Preliminary Experiments with Fungicides for Stinking Smut of Wheat.
No. 13	August, 1890	Experiments with Oats.
No. 14	December, 1890	Winter Protection of Peach Trees, and Notes on Grapes.
No. 15	December, 1890	Additional Experiments and Observations on Oat Smut.
No. 16	December, 1890	Experiments with Sorghum and Sugar Beets.
No. 17	December, 1890	Crossed Varieties of Corn, Second and Third Years.
No. 18	December, 1890	Experiments with Forage Plants.
No. 19	December, 1890	Germination of Weeviled Peas. Garden Notes on Potatoes, Beans, and Cabbage.
No. 20	July, 1891	Wheat.
No. 21	August, 1891	Stinking Smut of Wheat.
*No. 22	August, 1891	Smut of Oats; Smut and Rust of Wheat.
*No. 23	August, 1891	Smut of Sorghum and Corn.
*No. 24	September, 1891	Staggers of Horses.
*No. 25	December, 1891	Sorghum for Sugar.
*No. 26	December, 1891	Varieties of the Strawberry.
*No. 27	December, 1891	Crossed Varieties of Corn.
*No. 28	December, 1891	The Experimental Vineyard.
*No. 29	December, 1891	Oats.
*No. 30	December, 1891	Corn.
*No. 31	December, 1891	Sugar Beets.
*No. 32	December, 1891	Feeding Stuffs, and the Development of Grain Crops. Soy Beans.
*No. 33	August, 1892	Experiments with Wheat.
*No. 34	September, 1892	Experiments in Feeding Steers.
*No. 35	December, 1892	*Actinomycosis bovis*, or "Lumpy Jaw" of Cattle. Some Observations upon Loco.
*No. 36	December, 1892	Experiments with Sorghum and with Sugar Beets.
No. 37	December, 1892	Experiments in Potato Culture.
No. 38	March, 1893	Preliminary Report on Rusts of Grain.
No. 39	August, 1893	Experiments in Feeding Steers, II.
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No. 44	December, 1893	Further Study of Native Grapes.
No. 45	December, 1893	Experiments with Corn.
No. 46	May, 1894	Rusts of Grain, II.
No. 47	August, 1894	Experiments with Wheat. Experiments in Feeding Steers, III.
No. 48	December, 1894	Six Years' Experience with Ensilage. Some Forage Plants. Renovating a Prairie Pasture.
No. 49	May, 1895	Cattle Poisoning by Potassium Nitrate. Mastitis.
No. 50	June, 1895	Kansas Weeds, I—Seedlings.
No. 51	June, 1895	Steer Feeding, IV—A Comparison between Pure-bred Shorthorns and Scrubs.
No. 52	September, 1895	Kansas Weeds—Preliminary Circular on Distribution.
No. 53	October, 1895	Pig-feeding Experiments with Corn, Wheat, Kafir-corn, and Cottonseed.
No. 54	December, 1895	Experiments with Oats.
No. 55	December, 1895	Small Fruits by Irrigation. Culture of Strawberries.
No. 56	December, 1895	Experiments with Corn. Experiments with Kafir-corn.
No. 57	June, 1896	Kansas Weeds, III—Descriptive List.
No. 58	June, 1896	Cornstalk Disease of Cattle.
No. 59	August, 1896	Experiments with Wheat.
No. 60	September, 1896	Steer-feeding Experiments, Series V.
No. 61	November, 1896	Kafir-corn, Corn and Soy-bean Meal for Pigs. Kafir-corn and Corn-meal for Cattle.

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*No. 68....	June, 1897...........	Soil Moisture.
*No. 69....	June, 1897...........	Some Diseases of Cattle.
*No. 70....	July, 1897...........	Vegetable Growing.
*No. 71....	July, 1897...........	Experiments with Wheat.
*No. 72....	July, 1897...........	Growth of Young Stock.
*No. 73....	July, 1897...........	Miscellaneous Fruit Notes.
*No. 74....	July, 1897...........	Experiments with Oats.
*No. 75....	August, 1897.........	Root Development of Forage Plants.
*No. 76....	February, 1898......	Kansas Weeds, V—Vegetative Propagation.
*No. 77....	March, 1898.........	Some Insects Injurious to the Orchard.
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*No. 80....	June, 1898...........	Kansas Weeds, VI—Distribution and Other Notes.
*No. 81....	September, 1898.....	Feed and Care of the Dairy Cow.
*No. 82....	January, 1899.......	The Potato-stalk Weevil.
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No. 84....	April, 1899...........	Cold Storage for Fruit.
*No. 85....	April, 1899...........	The Growth of Alfalfa in Kansas.
*No. 86....	June, 1899...........	Press Bulletins Nos. 1 to 34.
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*No. 88....	May, 1899............	Keeping Milk in Summer.
*No. 89....	June, 1899...........	Soil Moisture.
*No. 90....	January, 1900.......	Alfalfa in Eastern Kansas.
*No. 91....	February, 1900......	Swine-plague.
*No. 92....	March, 1900.........	A New Drought-resisting Crop—Soy Beans.
No. 93....	March, 1900.........	Kafir-corn.
No. 94....	April, 1900...........	Sugar Beets, 1899. The Station Publications. Partial Index to Station Publications.
*No. 95....	April, 1900...........	Fattening Hogs with Drought-resisting Crops.
*No. 96....	May, 1900............	Soil Inoculation for Soy Beans.
No. 97....	May, 1900............	Skim-milk Calves.
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*No. 100...	March, 1901.........	Soy Beans in Kansas in 1900.
*No. 101...	January, 1901.......	Notes from the Plum Orchard.
*No. 102...	May, 1901............	Forage Plants for Kansas.
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*No. 113...	June, 1902...........	Baby Beef.
No. 114...	June, 1902...........	Growing Alfalfa in Kansas.
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No. 116...	January, 1903.......	Destroying Prairie-dogs and Pocket-gophers.
No. 117...	May, 1903............	Bacteria of the Soil.
No. 118...	May, 1903............	Flesh and Fat in Beef.
No. 119...	September, 1903.....	Press Bulletins Nos. 71 to 124.
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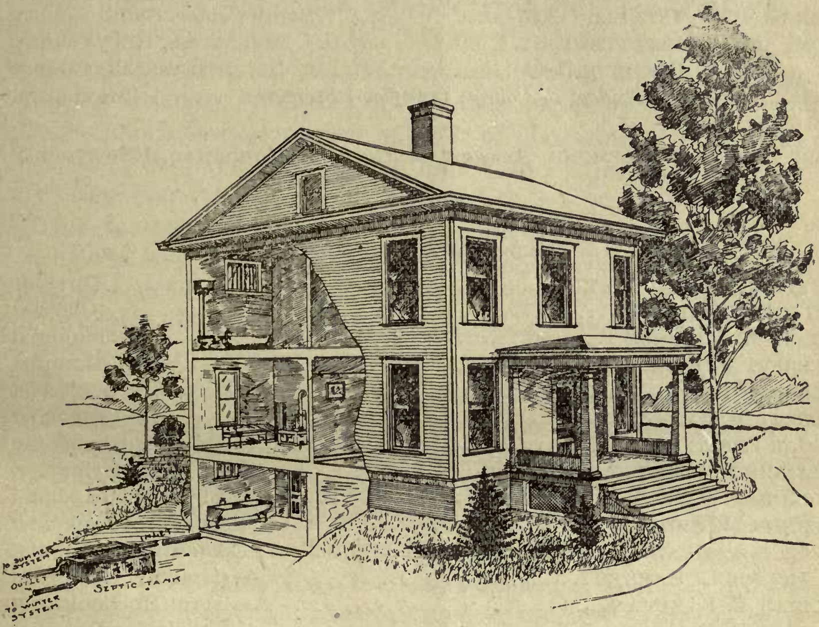
AGRICULTURAL EXPERIMENT STATION, Manhattan, Kan.

February, 1907 Bulletin 143

Kansas State Agricultural College

Agricultural Experiment Station

Disposal of Dairy and Farm Sewage, and Water-supply



The septic tank as used in connection with a farmhouse.

BY

Oscar Erf

MANHATTAN
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OF THE

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Disposal of Dairy and Farm Sewage, and Water-supply

By Oscar Erf

The health of the public depends upon cleanliness. Since the dairy products of the United States stand first as a food, it is essential that they should be produced under the strictest sanitary conditions. With this in view it is our purpose to give a few suggestions as to the proper manner of disposing of farm sewage from the cow barn, milk house, dairy, and from the dwelling, or any other place that is closely situated to the dairy plant.

This matter is of greatest importance on dairy farms, for if conditions are kept filthy they very soon breed diseases which affect not only people who live on the farm, but consumers as well; for we now well know that many diseases are transmitted through milk and other dairy products.

Where many cows are kept in small places, and where the population is large, sanitary improvements are most important to health and prosperity. Where fewer animals are kept and where the country is sparsely settled, sanitary precautions are not so necessary, for nature usually takes care of these conditions. In cities the sanitary conditions of homes and surroundings are chiefly maintained by a system of coöperation and centralization which brings into existence extensive sewage systems, water-supplies, and the collection of house waste by public authority. Rules are prescribed and enforced under which the individual household must avoid all such conditions which are likely to prove dangerous to the health of the immediate neighborhood, and to the entire community.

The principle underlying the disposal of the sewage on the farm should be essentially similar to that of the cities. The proper method of disposing the sewage on the farm eliminates a great many dangers which constantly face the farmer. (Fig. 1.) One of the most serious dangers is contamination of the water-supply. If the water-supply on the dairy farm is contaminated it will be impossible to produce sanitary milk, since utensils washed in impure water will directly affect the milk. The cesspool, so common on dairy farms, quite frequently secures a direct connection with the well, especially if located near it, and thus contaminates the water. Polluted water comes from improper sewage disposal, and is generally infected from household excrements, barn-yarn drainage, etc. Its use leads to bowel disturbances, typhoid fever, and dysentery, affecting man and beast alike. The health of large communities of people who draw their food supply from the country is in a measure dependent upon the healthfulness of the farming community. In fact, there is scarcely a city child whose health is not in a degree dependent upon the sanitary condition of the barn and house of the dairyman. Milk has frequently been shown to be the means of disease distribution.

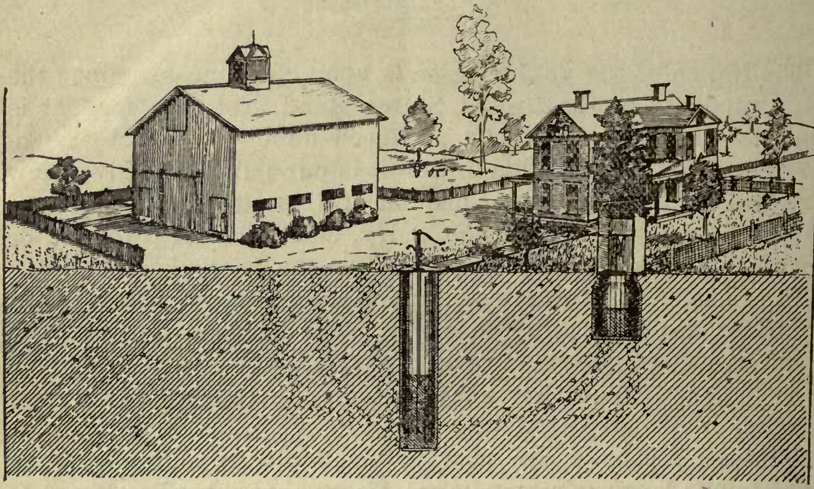

FIG. 1.—Showing method of contamination of well water from manure yards and cess pools.

With these conditions before us it is absolutely necessary to have a good sewage-disposal plant on every farm. Health cannot be measured by cost; for a small cost should not stand in the way to any great extent in erecting a plant that is effective for this purpose.

The Dairy Department of the Kansas State Experiment Station has for the past few years been experimenting on the different methods of sewage disposal, and it is now ready to advocate a system that is comparatively inexpensive, and is practical for every farm; in fact, in some cases it has proven to be a source of great profit when used for irrigating and fertilizing truck patches and farm crops. It has furthermore proven to be a labor-saving contrivance in the way of cleaning cow stables, providing the stables are properly constructed, as shown in (Fig. 2 and 3.)

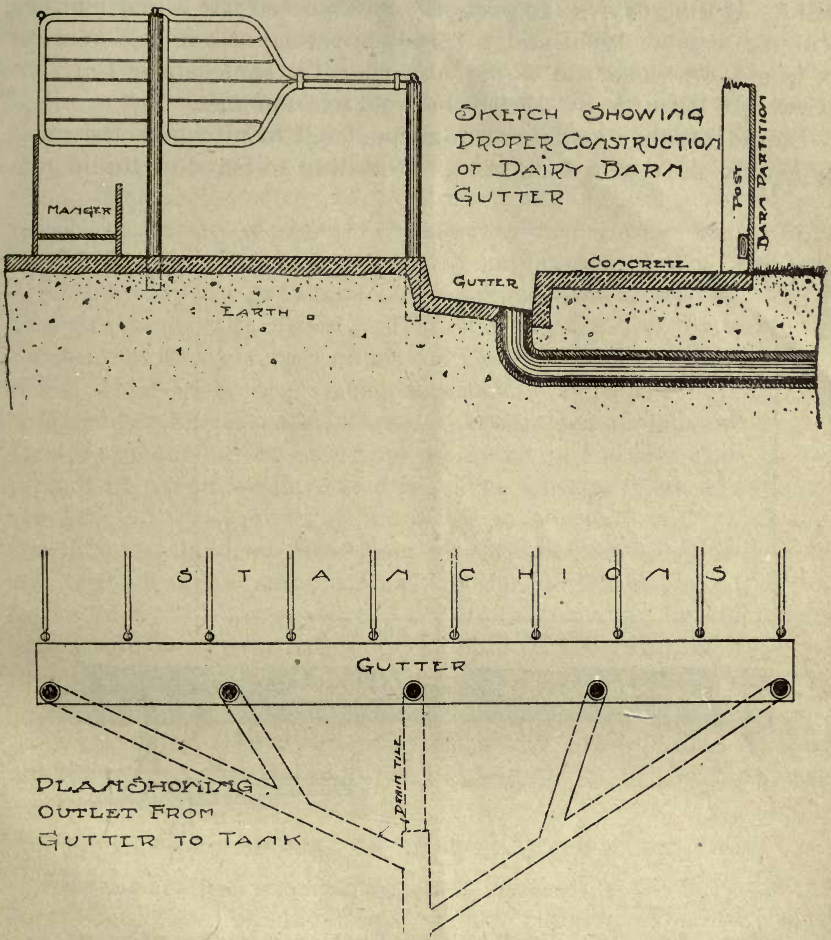
SKETCH SHOWING PROPER CONSTRUCTION OF DAIRY BARN GUTTER
MANGER
EARTH
GUTTER
CONCRETE
POST
BARN PARTITION
STANCHIONS
GUTTER
DRAIN TILE
PLAN SHOWING OUTLET FROM GUTTER TO TANK

FIG. 2.—Showing a sketch of the proper construction of a gutter in a dairy barn which will remove the liquid manure. This gutter should be twenty-seven inches wide. The bottom should be inclined one-half inch to the foot. The spaces between the outlets may range from twelve to fifteen feet. The depth of the gutter on the cow's side should be at least one foot. The advantage of this gutter over a narrow trough or half circle is as follows:

It has been the experience with dairymen having square, narrow gutters back of cows that the solid manure blocks the flow of the liquid manure. Hence it is necessary to remove by hand both the liquid and the solid manure. With the scheme as shown above the gutter is wide and the solid manure is voided on the side of the gutter on which the cow stands. The gutter being wide, the solid manure does not cover the bottom of the gutter, thus allowing the liquid manure to flow on the lowest end of the gutter, and from there to the sewage disposal system.

The average cow voids about 20,000 pounds of manure per year, of which approximately 9500 pounds are liquid and 10,500 pounds solid. If the gutters are properly constructed the liquid manure will take care of itself and will reduce the labor one-half of what it would be were the liquid absorbed by some absorbent like straw and then removed with the solid excrements.

Liquid manure contains a high per cent of nitrogen, the most expensive part of a fertilizer. According to Snyder, liquid manure from cows fed a well-balanced ration contains about 89 per cent water and 1.2 per cent of nitrogen; solid manure contains 76 per cent of water and .5 per cent of nitrogen. This shows the comparative high value of liquid manure, which, on average farms of Kansas, is allowed to flow into streams and pollute the same.

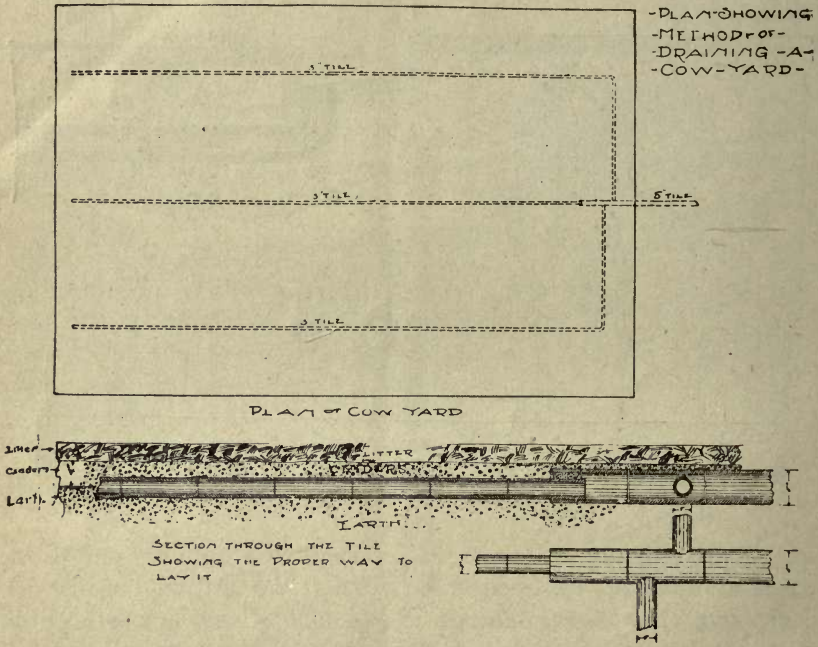

FIG. 3.—Showing method of drainage of a cow yard, or the covered-yard system.

According to Woll, the value of manure from a cow for one year, fed on a well-balanced ration, is estimated at $29.97. This is a source of income for the farmer which is seldom taken into consideration because his conditions are such that he is not able to take care of it. By means of a proper sewage-disposal system the value of this manure may be fully recovered, besides making conditions on the farm more sanitary.

MANNER OF DISPOSING OF SEWAGE

The disposal of sewage is brought about by the decomposition of the organic matter. All sewage is largely organic matter and water. All organic matter decays. This decaying process is simply the disintegrating action of minute organisms known as bacteria upon the solid parts of the sewage, dividing the same into such a form that it becomes fluid. The superficial layers of soil from six to twelve inches are thoroughly inoculated with bacteria. The action of the bacteria upon any organic material is to reduce the complex organic compounds into simpler compounds. Hence, decay is the destruction of complex substances that have been built up by growth. There are certain kinds of bacteria that can penetrate organic substances to a slight extent only. Some must have air, particularly oxygen, to decay a portion of the mass, while there are other bacteria that have the power of decomposing organic material without the presence of air or oxygen. In the system herein described it is chiefly the last kind of bacteria with which we have to deal. The sewage discharges into a receptacle that is air-tight, known as a "septic tank." This sewage is acted upon by these bacteria, which partially decomposes and liquefies the same. Most of the disagreeable odors are liberated by this process, and the liquid can then be discharged into an open stream with a great bulk of the running water, or into an irrigating system.

The process of decomposition in this septic tank is greatly aided by using a great quantity of water. This is an advantage on dairy farms, for water is used in abundance for washing utensils and cleaning the cow barns.

PLAN OF DISPOSING OF SEWAGE AFTER LIQUEFYING

As stated above, the sewage, after once being decomposed in a septic tank, can be discharged into a running stream or river without emitting offensive odors. This is the simplest way to dispose the sewage, but there are many farms which are not located so as to allow the sewage to be discharged into such a stream. For such a farm, in fact for every farm where it can be adopted, the disposal of sewage by irrigation is by far the best method. There are two methods used for irrigation: the surface method and the subsoil method. With the surface method liquid sewage is drained through glazed tile to a piece of ground set apart for this purpose. The ground is ridged and the sewage is allowed to flow over the ground in shallow channels. The liquid slowly disappears by filtering through the soil. Patches of ground that are wet must be carefully under-drained so as to allow the surplus water to be drained from the surface. This method of disposing sewage is objectionable from the standpoint that the sewage flows on the surface and animals crossing such fields may carry sewage on their feet, and if there are any disease germs in the sewage it may be carried from one place to another.

The safest method is subsoil irrigation. This consists of a system of underground porous tile, laid in the manner shown in Fig. 4, so as to allow the sewage to seep through the tile. The tile are connected directly with a septic tank and laid so as to leave approximately one-eighth of an inch between each tile in order to allow the sewage to seep through the tile into the soil. The main line should consist of a five-inch tile, depending somewhat upon the sewage. If a great amount of water is used with sewage, four-inch tile may be used. The lateral drains may be four-inch tile, or if the main drain is a four-inch tile the laterals may be three inch. Nothing smaller than a three-inch tile should be used for this purpose.

For irrigation purposes tile should be laid from eight to sixteen inches beneath the surface of the ground, with a gradual incline of one or two inches for every one hundred feet. The depth to which these tile should be laid depends on the nature of the soil. There should be two systems for each septic tank. One of these systems should be laid below the frost line for winter sewage disposal, while the one laid shallow is used for summer disposal. By this method the sewage which is so objectionable on the dairy farm or in the creamery is removed and is used for irrigating and fertilizing purposes.

This subsurface method of sewage irrigation is particularly profitable for intensive farming and horticulture. The author knows of a number of instances where in one year such a system has paid for itself by the increased crop production which resulted from irrigating and fertilizing the soil. It is authentically stated that a horticulturist in Ohio has grown enough berries on his irrigated and fertilized soil in one year to pay for three such sewage disposal plants.

CONSTRUCTION OF A SEPTIC TANK

There are numerous ways for building septic tanks. Some of these are shown in Figs. 5, 6, 7, and 8. Such tanks may be built of any tank material, but for durability it is preferable to construct them of brick, stone, or concrete. The partitions may be built of concrete or wood. It is generally advisable to build them of concrete if convenient to do so. The tank should be built as

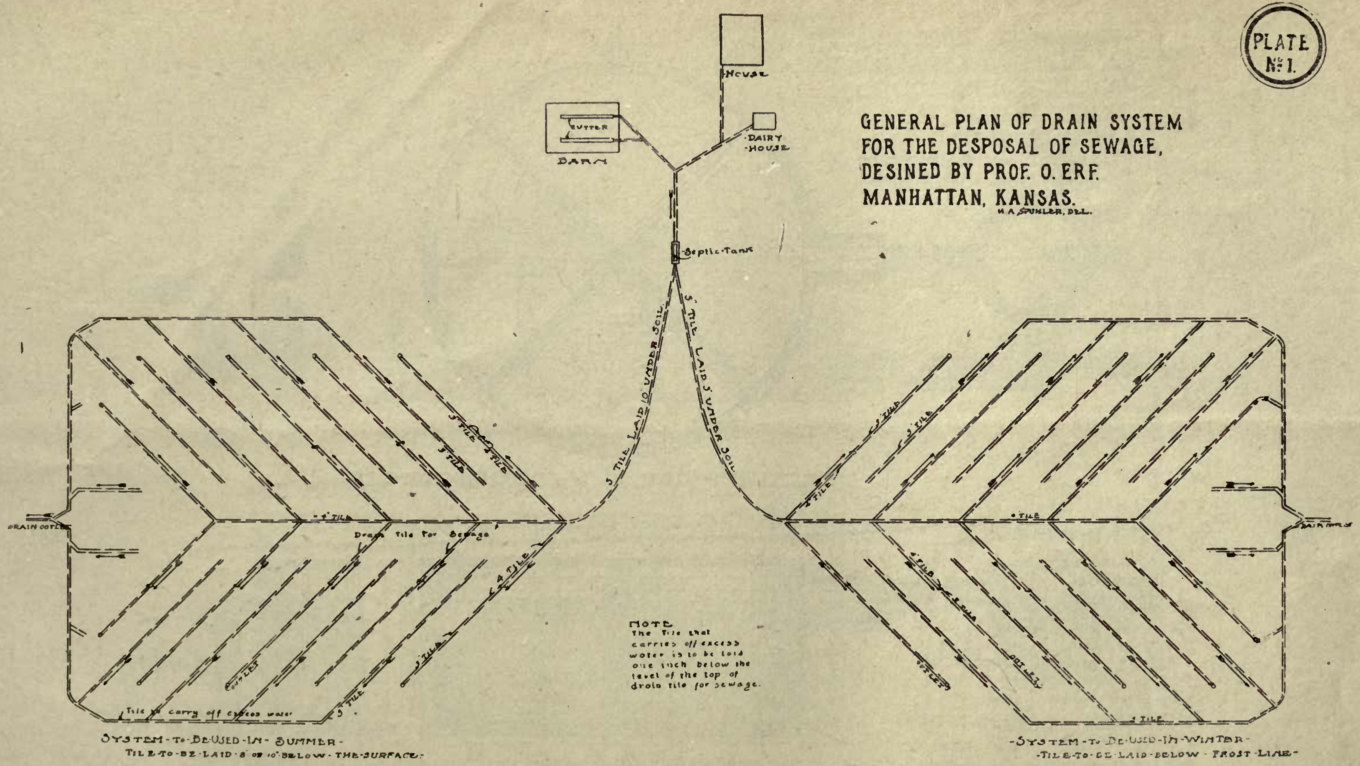
PLATE No. 1.
GENERAL PLAN OF DRAIN SYSTEM
FOR THE DESPOSAL OF SEWAGE,
DESINED BY PROF. O. ERF.
MANHATTAN, KANSAS.
H. A. SPIKLER, DEL.
HOUSE
BARN
GUTTER
DAIRY HOUSE
Septic Tank
5" TILE LAID 10' UNDER SOIL
5" TILE LAID 5' UNDER SOIL
DRAIN OUTLET
4" TILE
Drain Tile for Sewage
5" TILE
4 TILE
OUTLET
Tile to carry off excess water
NOTE
The Tile that carries off excess water is to be laid one inch below the level of the top of drain tile for sewage.
SYSTEM TO BE USED IN SUMMER
TILE TO BE LAID 8' or 10' BELOW THE SURFACE.
SYSTEM TO BE USED IN WINTER
TILE TO BE LAID BELOW FROST LINE

FIG. 4.—Showing a complete irrigating system with dairy house and residence attached with the same system of the barn. It is essential to provide for an air vent at the end of each branch of tile to allow the escape of air in the tile when sewage is emptied into the irrigating system.

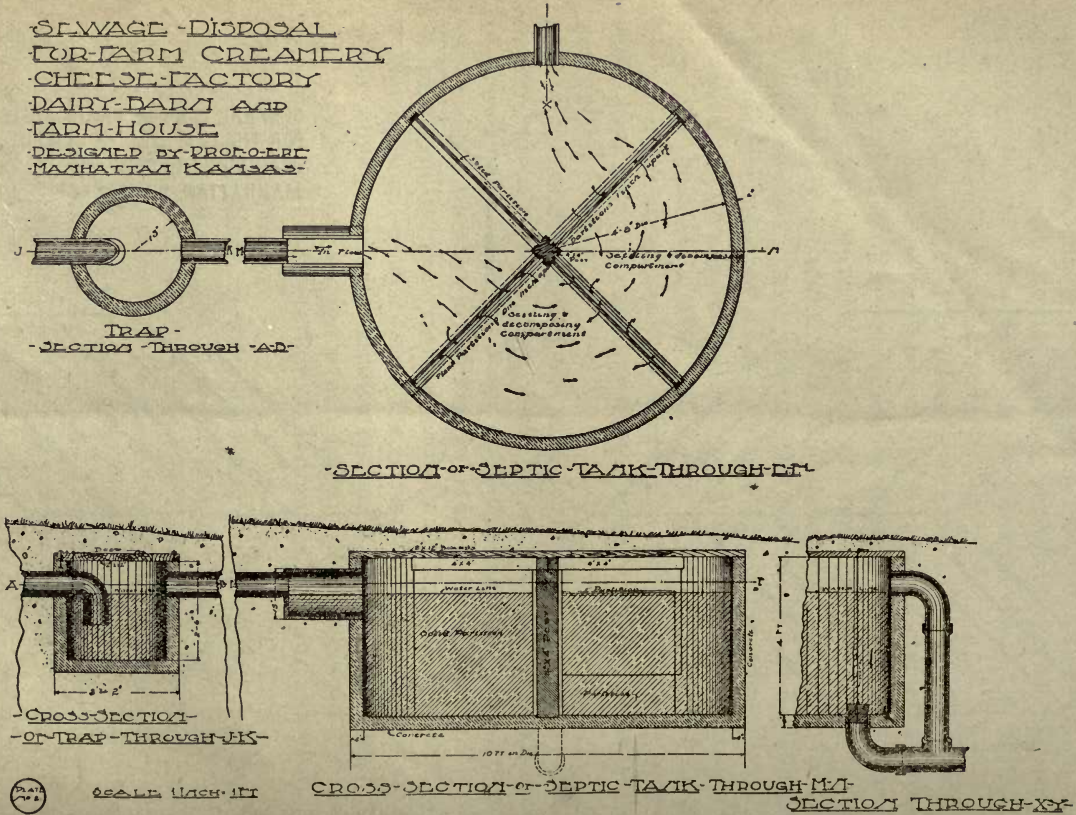

FIG. 5.—Showing the detailed construction of a round septic tank, with four compartments. The partitions are made of wood. This septic tank disposes of the sewage by over-flow. This plant can be attached to an irrigating system but the plug must be pulled whenever irrigation is wanted.

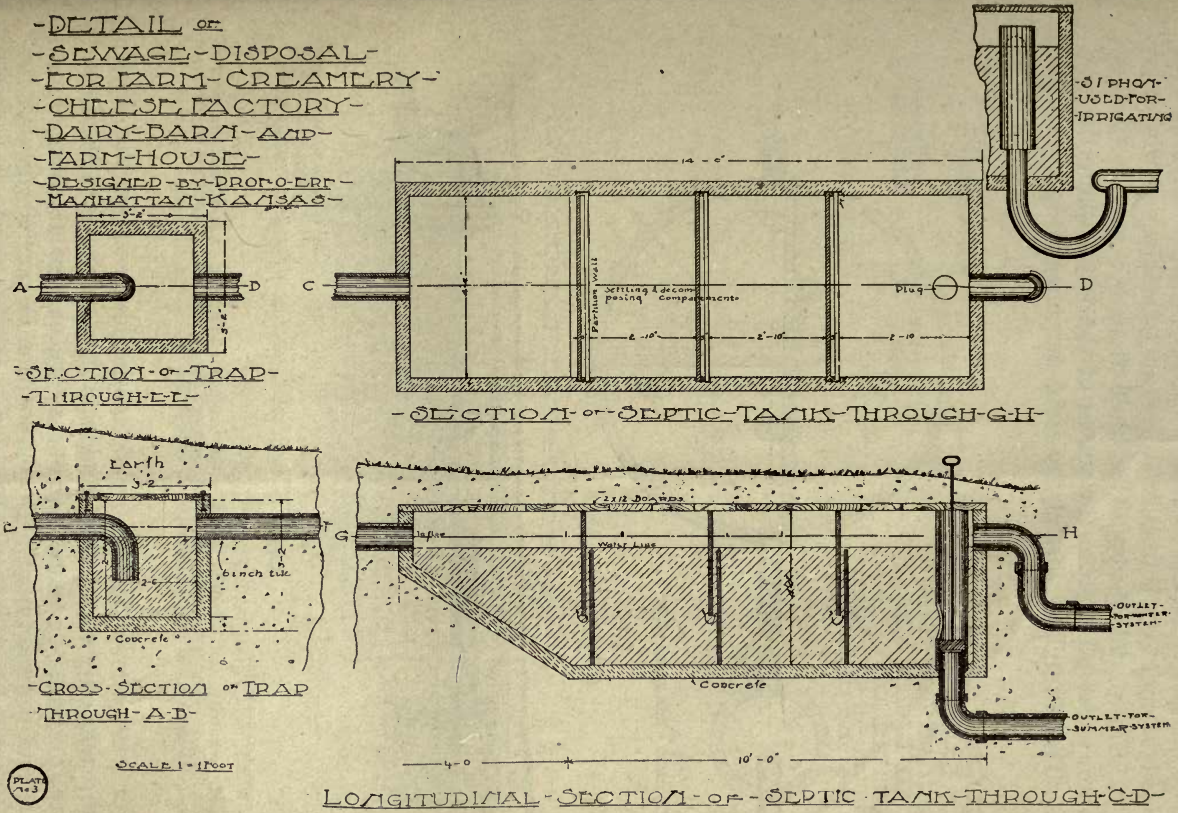

FIG. 6.—Showing the detailed construction of a rectangular tank, a combination disposal plan in which the over-flow runs into the winter system, and if irrigation is wanted the rod is drawn and runs into the system for summer irrigation. In irrigating it is essential to have the whole irrigating system filled at once, to distribute the sewage uniformly. To accomplish this it is necessary to have a large drain tile connecting the septic tank to the irrigating system, and provided with a large outlet, so as to allow the filling of the irrigating system as quickly as possible. In this way every branch of the distributing system is filled with sewage. A siphon may take the place of rod and plug. A siphon works automatically.

nearly air-tight as possible, with a slight vent of one-half inch pipe to allow the gas to escape. There should be a trap door in the first compartment so as to allow the same to be cleaned when necessary. The partition should be built in such a way as to allow the water to be taken from the center of the tank, where the sewage is all liquid. The most of the solid particles of sewage either sink or float; consequently, by taking the sewage from the center of the basin only such liquid and particles as are of a semi-solid nature, or have the same density as water, are discharged into the second compartment. Decomposition is carried on still further in this compartment. When transferred to the third compartment it should be thoroughly liquefied. When transferred to the fourth compartment it is ready to be deposited into the irrigating system, where it is to be taken up by the soil. If the sewage is not to be utilized for irrigating purposes, but drained

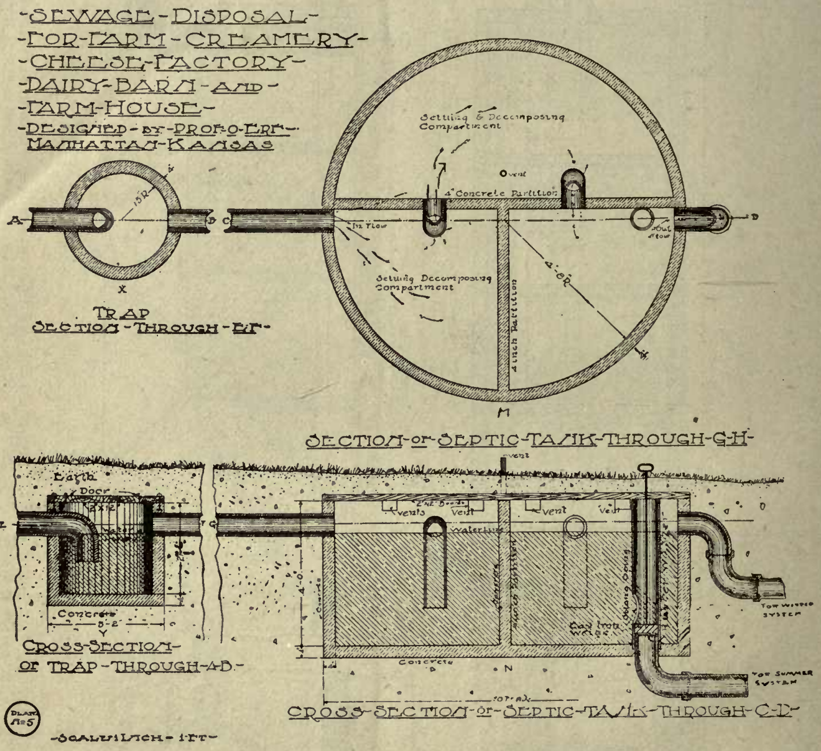

FIG. 7.— Showing the detailed construction of a round septic tank which can be connected with a summer and winter system of sewage disposal. This tank can be used where the sewage is more liquid than in the case of tank in Fig. 5.

directly into a stream, the sewage may be taken from the top of the tank, as shown by the connection marked X, in Fig. 5, and H, in Fig. 6. In case the tank is to be cleaned, the plugs of the same systems may be removed and thoroughly drained. For irrigating purposes it is advisable to use a siphon. This siphon removes the water from the last compartment of the septic tank automatically

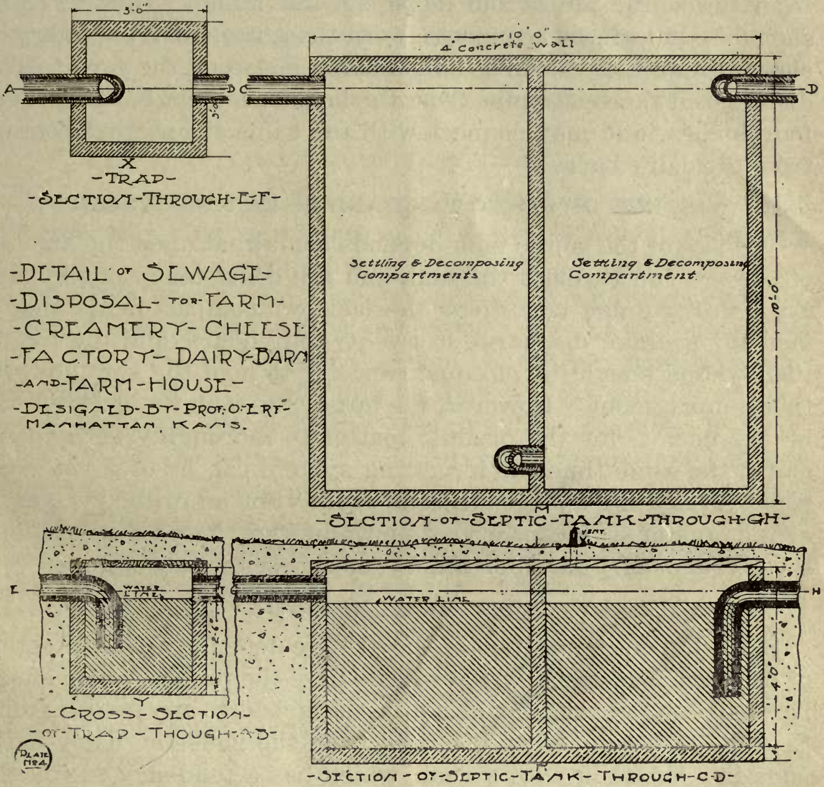

FIG. 8.—Showing a simple square septic tank, used in places where there is mostly liquid sewage to be disposed of.

at intermittent discharges. The discharge at one time of a quantity of sewage large enough to fill the irrigating system will scour the system of pipe; besides it more uniformly distributes the sewage throughout the whole irrigating system. Without a siphon, on pulling the plug occasionally the same effect can be secured, but if the sewage is allowed to overflow into the tile it will run out into the soil nearest to the septic tank. In the latter case the soil will become over-saturated with the liquid, and the purification of the sewage in the soil is thereby rendered imperfect.

SEWER CONNECTION TO SEPTIC TANK

Sewer connection from the cow barn to the septic tank should be constructed of not less than five-inch glazed sewer pipe, and preferably six-inch pipe. The sewer should be connected directly with the gutters and allowed to enter into a trap, as shown in designs herewith. This trap is a small box, in which a pipe bends down into the liquid to prevent the gases or odors coming from the septic tank from going into the stable. Similar traps should be put in when connected with the gutters of a creamery or cheese factory, or to the house or dairy house on the farm. The diameter of the sewer pipe from the house need not be more than four inches, and may connect with the same tile as that coming from the dairy barn.

THE SIZE OF SEPTIC TANK AND IRRIGATING SYSTEM

The size of the septic tank depends somewhat upon the amount of sewage run through the tank and the consistency of the sewage. For average conditions the last two compartments should hold the average discharge in twenty-four hours, and the irrigating system should be of equal capacity to hold the sewage from this compartment. However, the larger the tank the greater will be the chance for the organic matter to thoroughly decompose, and at the same time the irrigating system can be of greater capacity, irrigating a larger tract of land. For an ordinary farm a septic tank of such capacity as shown in Figs. 5 and 6 will handle the average dairy farm, creamery, or cheese-factory sewage.

NECESSITY OF COMPARTMENTS

Since the decomposition of the sewage depends upon the action of bacteria, it is essential in order to have the process go on effectively that the germs should not be disturbed to any great extent. Sewage, as a rule, when it comes from the house or dairy barn, runs into the tank with a rush, which has a tendency to roil the sewage in the tank. To overcome this sudden rush a partition should be put across the septic tank close to the inlet of the tank, which is supposed to prevent the disturbance in the second, third and fourth compartments. However, it is quite impossible to regulate the force of sewage in such a manner as to prevent any disturbance in the second tank. For this reason it is advisable to put a third partition in the tank, which will give the germs a chance to act thoroughly upon the sewage before it enters the discharge tank, or last compartment.

As the sewage travels from one tank to another it is gradually purified, and as it flows into the discharge tank all organic matter is in a liquid or semi-liquid state. At this point the sewage is practically deprived of any disagreeable odor, and that which is still retained is not objectionable. To prove the efficiency of this method of purification, sewage after passing through the tank, being thoroughly decomposed, can be kept for weeks at a very favorable temperature, showing no signs of the development of putrefactive odors. It should require from three to four days, however, for sewage to pass through this tank to thoroughly deodorize it. Three partitions in a tank, as described above, have proven very efficient. However, a tank with two compartments is very satisfactory, but in no case can a tank without compartments be recommended.

LOCATION OF SEPTIC TANK

There should be a slight fall from the stable to the septic tank, and from this tank to the irrigating system. A septic tank can be located as far as convenient, or as near as desirable, to the traps. This is a matter that depends upon conditions entirely. However, in all cases the inlet and outlet drains of the system, as far as the point of irrigation, should consist of sewer pipe with joints cemented. A preferable location for the tank is about a foot to eighteen inches in the ground. This prevents freezing, which checks decomposition. However, there are instances in which the slope of the ground from the stable to the irrigated field is so slight that the septic tank needs to be put above the ground. In that case it is advisable to cover the tank with earth, straw, or barn-yard manure, to prevent freezing.

PRECAUTIONS

Care should be taken that no strong disinfectant, such as corrosive sublimate, is allowed to be run into the septic tank from the stables or house, since any disinfectant prevents the action of the bacteria in the tank; consequently a large part of the sewage will remain in a solid form and the tank will soon fill up.

CLEANING OUT THE TANK

The frequency of cleaning this tank depends entirely upon the kind of sewage discharged into the tank. All organic matter is readily decomposed and will flow through the tank, as has been stated before, but inorganic matter, such as sand, crushed rock, cinders, etc., cannot be decomposed and will remain in the same. If due precaution is taken in not allowing too much of this inorganic matter to flow into the tank, there is little need of cleaning it. For a cow barn such a tank need not be cleaned oftener than once in eight months. The tank at the College has not been cleaned for two years, and there is at the present time not more than a foot of sediment in the bottom of the first compartment. For creameries and cheese factories these tanks need not be cleaned oftener than once a year.

SIPHON

The siphon to be used in this tank for irrigating purposes can be purchased from any plumbing concern.

COST OF A SEPTIC TANK

The cost of a tank depends somewhat upon the locality and the price of material in that locality. The following estimate is based on average prices:

COST OF TANK, FIG. 5.

Digging	$ 4 00
Concrete and labor	21 00
Lumber, 200 feet of 2-inch plank, @ $30 per M	12 00
Posts, 4x4	50
Labor	2 00
One 15-inch sewer pipe	75
Two 4-inch sewer-pipe bends	1 50
One 4-inch sewer pipe	50
One length of sewer pipe	25
Total	$42 50

COST OF TANK, FIG. 6.

Concrete and labor	$24 20
Digging	4 00
Lumber	9 00
Labor	2 00
Two sewer-pipe bends	1 00
One 4-inch T	50
Two 4-inch pipe	40
Total	$41 10

WATER-SUPPLY.

While this plan of sewage disposal will practically eliminate any pollution of well water, there are, however, other conditions to which due regard must be given to prevent any contamination of the well. It must be borne in mind that the well cannot be given too much care, for it supplies water to creameries, cheese factories, the dairy farm, and the household. Well water is usually contaminated in two ways: First, by surface water which runs directly into the well and, second, by barn-yard drainage, household slops, and cesspools.

Nearly all of the bacterial life exists in the upper strata of the soil. Soil ten or twelve feet below the surface of the earth is perfectly sterile, unless it has within it a crevice or opening so that surface sewage can run down. Therefore, due care should be taken in digging and constructing a well so that direct contamination will be prevented.

CONSTRUCTION OF A WELL

The well itself must be so constructed that the impurities cannot get into it from above or from the sides. Water should be filtered through ten to twelve feet of fine soil. To prevent the surface pollution, a water-tight wall should be built in a well down below the water level. This can be built of hard, burned brick and cemented on the outside. Clay should be pounded around this.

Where drilled wells are used, the lining of the well should be an iron tube driven into the bore and the outside should be flushed with thin cement. The well should be properly covered and the surrounding ground should be considerably higher than the general level of the soil. The walls should extend at least three feet above the surface of the ground and a ground fill made so that it will slope from the wall. The top of the fill should be covered with at least twelve inches of clay or loam, upon which it is advisable to have some sod or a layer of sand, or best of all a pavement sloping in all directions.

Owing to the great quantity of water needed in the dairy and the expense connected with the proper kind of filters, it is quite impracticable to use rain water.

CONCLUSION

If due precautions are taken in the disposal of sewage and in the proper construction of wells and care of waste and garbage, there is little danger of water becoming polluted, and it will be a great step toward increasing the healthfulness of dairy products.

The attractiveness of dairy farms depends largely upon the promptness with which all kinds of waste material are disposed of, and while there is an abundance of space on the farm to get rid of the rubbish and waste, it should be ever borne in mind that the removal of garbage should also be attended to as promptly as the disposal of sewage.

Kansas State Agricultural College

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Address, Agricultural Experiment Station, Manhattan, Kan.

FEBRUARY, 1908. BULLETIN 152.

Kansas State Agricultural College

Agricultural Experiment Station.

THE POCKET GOPHER.

The Prairie Pocket Gopher, *Geomys bursarius*. (Reduced.)

By

THEO. H. SCHEFFER.

MANHATTAN, KANSAS.
Published by the State; printed by the State Printer.
Topeka, 1908.
1612

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Address, *Director of Experiment Station, Manhattan, Kan.*

UNIV. OF
CALIFORNIA

LETTER OF TRANSMITTAL.

C. W. Burkett, Director, Agricultural Experiment Station,
Manhattan, Kan.:

SIR—I herewith transmit the manuscript of a report on the habits, life-history and methods of combating the pocket gopher. Mr. Scheffer has spent his available time during the past several years in this study, but has not heretofore published anything on the subject. It has been my pleasure to encourage the author and to urge this work to its completion. The recent remarkable increase of gopher work in alfalfa has led to such a widespread interest in the subject that I recommend the publication of this report as one of the regular Station bulletins.

Respectfully,

T. J. HEADLEE, *Entomologist.*

SUMMARY.

1. The prairie pocket gopher is most abundant in the central and northeastern parts of the state, particularly in the region drained by the Kansas river and the lower courses of its main tributaries. The plains pocket gopher is found in more scattering numbers in the western third of the state and down the Arkansas valley to some distance east of the great bend. Southeastern Kansas is comparatively free from gophers.

2. The gopher digs extensive runways in the subsoil of wild lands and cultivated fields, piling the excavated earth in mounds on the surface. These runways have no exit above ground. A single animal will throw up several mounds a day for weeks at a time. A gopher spends his entire time in his underground burrow.

3. Gophers breed in the late winter and early spring. Pregnant females may be found from January to May, but the young are nearly all born in March and April. There is but one brood a year. The number of young varies from three to six, and averages a little more than four.

4. The natural food of the pocket gopher consists of the fleshy roots it encounters in extending its runways, with the addition of some succulent vegetation drawn down into the burrow from above ground. Some food is stored in underground chambers for winter use.

5. Gophers are active at all seasons, but particularly so in the fall and spring. They do not hibernate. They throw up mounds any day in the year when the ground is not frozen too hard for mining operations.

6. The pocket gopher, by reason of his secluded life, has but few natural enemies. Bull-snakes, weasles, owls, cats and striped skunks destroy some of them, but cannot be depended upon to keep them in check.

7. Cultivated crops are damaged by the attacks of gophers on their root systems and by being covered with excavated earth. Much loss to the farmer also occurs through the obstruction to harvesting operations occasioned by the presence of the mounds. The alfalfa grower has the most ground for complaint, but nurserymen, orchardists, truckers and potato farmers also suffer heavy losses.

8. We have in Kansas two laws affecting the gopher; one a compulsory extermination law, the other a bounty law. The compulsory extermination law has two weak points, which render it practically inoperative. The bounty law has been tried and found wanting. Better results can be obtained, and at much less cost, by the plan of furnishing poison at the expense of the county or township.

9. Poisoning is the best method of combating the pocket gopher we have so far discovered. Trapping is effective, but slower than poisoning. Fumigation does not give good results, and we do not therefore recommend it. The poisoned bait that has given us the best results is soaked corn treated with a syrup prepared by the Experiment Station. Raisins, prunes and pieces of apple, potato and sweet-potato into which crystals of strychnine have been inserted also make excellent baits, but require much more time in preparation than the corn bait.

10. Extermination of the pocket gopher in Kansas is not to be looked for, but communities may be entirely freed from the pest by persistent and concerted action on the part of landowners.

THE POCKET GOPHER.

By THEO. H. SCHEFFER.

INTRODUCTORY REMARKS.

DURING the last three years the author of this bulletin has devoted a considerable amount of time to gathering data and establishing facts relative to the Kansas species of pocket gopher. Direct observations and experiment in the field have constituted the larger part of the work considered necessary to the preparation of a paper having any real practical value. An extensive correspondence, carried on independently and also in connection with the sale of gopher poison by this department during the past five years, has added materially to our knowledge, particularly of the distribution and depredations of the animal. In connection with the work a number of extensive trips have been made to various parts of the state, including the banner alfalfa counties, the irrigated lands of the Southwest, the potato-growing districts of the Kansas valley, and nurseries and orchards in several quarters.

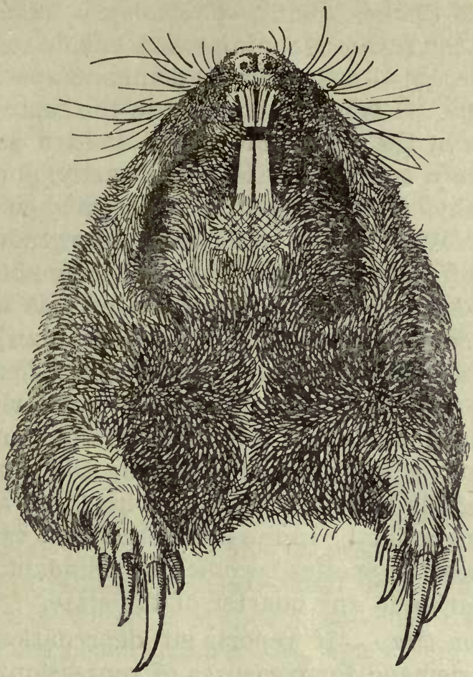
The important bearing of pocket-gopher problems on agricultural interests has become very apparent in recent years. No other species of native mammals of the state will rank with the pocket gopher in extent of injury to crops and obstruction to work in harvesting them. From an economic standpoint, therefore, the gopher is our most destructive mammal. There can be no doubt, either, that the numbers of the animal are increasing from year to year, especially in the alfalfa-growing districts of central Kansas. In many localities there are ten gophers now where there was but one a few years ago. With the steady increase in the acreage of alfalfa one may expect to see still more rapid multiplication of the species. This valuable crop (alfalfa) furnishes just the conditions necessary to make life easy for a pocket gopher. The roots of the plant are thick and succulent and extend deep enough to supply the wants of the animal in his natural range, or even when he is burrowing below the limits of frost. This food supply never fails. Then, too, the ground is not broken up by the plow for a period of years and the surface scraping given by the harrow or disk does not in the least disturb these burrowing rodents. Consequently vigilance on the part of every landowner and coöperation with his neighbor—nothing short of this—will rid a community of the pocket gopher. We cannot hope to exterminate the animal, for the conditions under which he lives are such as to render extermination practically impossible. Like mice and rats, the gopher is probably with us to stay. But the farmers of any community, as well as any individual landowner, can secure immunity from the ravages of the pest at little cost of time and labor. More than one thrifty farmer has assured me that if one keeps careful watch of his acres, the career of any invading pocket gopher can be nipped short at an expenditure of time totaling not more than a few hours a year. The history of the prairie-dog and his elimination from the agricultural problems of western Kansas well illustrates what can be done in the case of the gopher. It is no longer a matter of seeking a solution for the gopher problem. Solutions are at hand, but we are lacking in persistence and coöperation.

DESCRIPTION AND DISTRIBUTION.

The common gopher, *Geomys bursarius,* belongs to a family of rodents differing in many respects from that including the squirrels. The term "gopher" should therefore not be applied either to the little striped ground squirrel of our prairies or to the larger gray burrowing squirrel, Franklin's spermophile.

General Appearance.—Our true gopher is a short, thick-set fellow, with capacious external cheek pockets. These are wholly outside of the mouth, and are lined with fine soft hair of a lighter shade than that covering the body. The latter is dark brown in color, lighter beneath, and so soft and silky that it is not readily soiled by contact with damp earth. Sometimes there are white patches of various sizes about the nose and throat. Occasionally a pure white specimen is taken. The tail is short and scantily covered with hair. The bead-like eyes are about as large as a No. 5 shot, and external ears are likewise not much in evidence. The incisor teeth are long and prominent, the upper pair being grooved longitudinally.

Size.—The adult animal varies somewhat in size in different



Head of prairie pocket gopher, showing entrances to cheek pockets and grooved upper incisors.

parts of its range. Specimens taken about Manhattan average ten to eleven inches in length from tip of nose to tip of tail. The latter is about three and one-fourth inches long. The hind foot measures one and one-third inches. The average weight is very close to twelve ounces. The males are heavier, larger, and broader in the shoulders than the females.

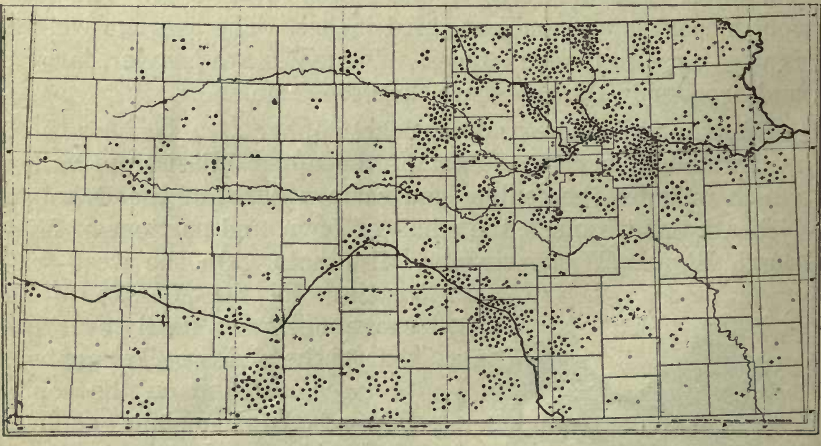
Distribution.—The prairie pocket gopher, *Geomys bursarius*, is distributed over that part of the upper Mississippi valley which includes the central and eastern parts of the Dakotas, Nebraska and Kansas, the whole of Iowa, and portions of Missouri, Illinois, Wisconsin and Minnesota. On the west—excepting in the Dakotas — its range meets and partly overlaps that of the plains pocket gopher, *G. lutescens*, and on the south that of the Louisiana gopher, *G. breviceps*. In the western part of the Dakotas *Geomys* is

Front foot of prairie pocket gopher.

replaced by a distinct genus—*Thomomys*—inhabiting nearly the whole of the Rocky Mountains and Pacific regions.

Kansas Species.—In Kansas the dominant species of gopher is *G. bursarius.* It is most abundant in the central and northeastern parts of the state, and ranges at least as far west as the ninety-ninth meridian. Here it is partly, and a little further west fully, replaced by the paler, sand-colored species, *G. lutescens.* Whether the two species intergrade on the common border of their respective ranges I have not been able to determine. At any rate, a discussion of this matter comes within the province of a technical rather than an economic bulletin. In no part of western Kansas have I found the plains pocket gopher very plentiful. It is more scattering in its distribution than *G. bursarius,* being locally abundant only in the gravel flats along the streams or among the sand-hills. The harder soil of the buffalo-grass tracts has little attraction for this burrowing animal. In the lower Arkansas valley of south-central Kansas the species becomes as abundant, however, as does *G. bursarius* in any quarter of the state.

Distribution Map.—If reports of depredations by pocket gophers and demand for measures of repression and extermination can be taken as an index to distribution, it may be seen from the accompanying map that *Geomys bursarius* is most abundant in the region drained by the Kansas river and the lower courses of its main tributaries. The area of greatest



Distribution map. The number of dots represents the number of cans of gopher poison sent out by the Station to various points in the state. The distribution of the dots will thus serve to indicate roughly the local occurrence or absence of the pest in destructive numbers.

infestation is also shown to include that portion of the Arkansas valley east of Great Bend, but here the plains species is the more abundant. A personal survey of the valleys of the Kansas, the Blue, the Republican, the Solomon, the Smoky Hill and the lower Arkansas valley confirms the evidence of the map to which I have referred. Southeastern Kansas seems to be comparatively free from the pest, at least in numbers sufficient to make it troublesome. In this region and along the south-central border of the state the range of *G. bursarius* probably meets that of the Louisiana pocket gopher, *Geomys breviceps*. The evidence of this is shown by specimens from the valley of the Ninnescah—now in the zoölogical collection at Washington—having some characteristics of both species.

HABITS.

The pocket gopher is an excellent illustration of an animal adapted to a particular environment. Built short and stocky, like a Hungarian miner, it is able to excavate with ease and dispatch the intricate system of long, branching, subterranean galleries in which it spends practically its entire life. Its shoulders are broad and its fore legs strong and sinewy, ending in stout claws that can rapidly rake a passage through a wall of earth. In mining operations the claws are assisted by a pair of long and sharp incisor teeth curving from the upper jaw. Its eyes are very small and their range of vision quite limited, as has been proven by experiments with animals kept in captivity. In fact the animal can have no possible use for eyes except in the brief moments it spends at the exists of its burrow when throwing out earth. As might be expected, a study of the animal's reactions to stimuli shows that its sense of touch and of smell are exceptionally well developed. The short, stubby tail, nearly devoid of hair, is particularly sensitive to touch.

The greater number of burrowing mammals, like the prairie-dog, the spermophile and the woodchuck, spend most of the daylight hours in fine weather above ground. The interesting little kangaroo rats and their ilk come out at night to thread their tiny pathways in the sand fields or report their errands in delicate tracery on patches of snow. The pocket gopher, on the other hand, cares neither for the enticing warmth of sunshine nor the witchery of moonlight, but sticks to the darkness of his tunnels. In watching gophers push out the earth when extending their burrows I have never seen one expose more of the body than the head, and usually one can catch a glimpse of the nose only, as with a quick upward flirt of this member the animal flings the dirt from the exit. As the earth is sometimes pushed to a considerable distance from the temporary opening, it is likely that the gopher must of necessity emerge entirely from his burrow at times. This he no doubt does under cover of darkness, for it is a matter of common observation that after a busy hour or so in the early morning very little dirt flies again until near sunset, except perhaps on dark, cloudy days. No evidence of tracks or traces of foraging indicates that the animal ordinarily ventures farther than its mound of earth, however, even in the night. At certain seasons, though, particularly when many of the young generation of that year are setting up in business for themselves, the natural instinct of all animals to extend the limits of their range impels the gopher to roam about. This is evidenced by the sudden appearance in late summer and in autumn of new mounds, like pioneer shanties, in fields remote from other gopher habitations. At this season we occasionally encounter a claim seeker abroad even in the daytime. In late autumn and early winter, too, the males no doubt wander about more or less.

The Burrow.—Except where an invader has recently established himself in new territory, it is practically impossible to determine the limits of a gopher's burrow. The work of excavating is usually carried on at a depth of eight to ten inches below the surface of the ground, but the animal sometimes ranges lower in loose, sandy soil where succulent roots penetrate deeper. The average diameter of the burrow of the prairie pocket gopher is about three inches; large enough that one may usually thrust the hand and arm back into it as far as he can reach. These data are easily obtained; but when one undertakes to map out the course of the main runways, the branch tunnels and their intersections, the pockets and the short laterals, he has before him a task that might well appal a military engineer in the wilds of a jungle. In a field that is even fairly well populated by gophers the runways of different individuals must of necessity frequently intersect each other, for it cannot be supposed that all the numerous subway crossings one exposes in digging along the tunnels are parts of one animal's private labyrinth. A prairie-dog or a spermophile digs a burrow very much like that of his neighbor; but it must be borne in mind that these animals are constructing homes, not extending passageways in search of food. The gopher follows his own sweet will in mining. Here a chance for easier digging turns him aside; there a promising lead of succulent roots entices him the other way. Heading everywhere in general and nowhere in particular, he may, in the course of a year, explore the length and breadth of a field of many acres. At irregular intervals he excavates a short lateral obliquely upward to the surface of the ground. Through these the loosened dirt is carried and thrust out in heaps. The presence of a gopher is thus easily detected by the lines of mounds, varying in size from a hatful to one or even several bushels of dirt. A study of a fresh mound reveals the plan of construction. The dirt is carried out of the opening and distributed radially, very much as miners dispose of the useless shale from a coal-pit. Usually the dump extends only part way around the opening, but sometimes the mound has the shape of a cone with a crater at the top. Where surface vegetation hinders the work, the piles of dirt are more irregular.

The Mound.—In removing the excavated earth from the burrow the gopher pushes his load before him in armfuls, so to speak. At the exit it is thrown out with a quick flip of the nose until the enlarging mound compels the animal to come out and dump the material down the slopes. After these become so steep that the material rolls back into the opening much dirt still boils up from beneath under the pressure of a powerful pair of shoulders. A wrinkled ring of earth on the completed mound usually identifies the point of the last outthrusts. After scraping away a mound from the harder surface of the ground, one may search in vain for the lateral leading to the burrow. The miner has packed it so tightly that the plug is as firm as the surrounding earth. Here and there a gopher burrow enlarges into a chamber of moderate size. Some of these are partly filled with dry grass; others are used for food storage. Not infrequently one finds a pocket extending upward, as though the animal had started to dig an exit but had abandoned the task for some reason or other.

Mole Runways.—The ridges and mounds of earth thrown up by moles are often incorrectly supposed to be the work of gophers. A little careful scrutiny will soon reveal the difference. The gopher piles up the dirt on the surface of the ground, building a mound by the addition of load after load on top of that already deposited. A mole simply heaves up the dirt from beneath, forming piles which show radiating cracks. Associated with these piles are the surface ridges made by the animal when ranging in search of food. The feeding runways of the gopher never show in surface ridges.

Breeding.—But little information along this line is obtainable in the literature accessible at this Station, and some of the statements therein made are, in the light of our own investigations, found to be more or less erroneous. The pocket gopher lives such a secluded life in its underground burrows that direct observations of its breeding habits require considerable painstaking effort. I have never been able to find a litter of the young myself, although I have explored a great many burrows in studying the animal. Occasionally, though, I have run across a nest of soft, dry grass that had probably been constructed for the purpose of rearing the young.

As might be expected of animals living in such comparative security, the pocket gopher is not a very prolific breeder. It certainly rears but one litter a year in this locality, for I have examined scores of specimens in all months of the year and have found the embryos only in late winter and early spring. The number of young in a litter varies from three to six and averages a little more than four. Very rarely only two embryos are found in the uteri.

Quite early in the spring, before the snows are fairly gone, the male gophers are said to roam about in search of mates. As I have never encountered one on such amorous errands intent I have not been able to verify the statement. It is entirely probable, however, that for reasons of personal safety such excursions are undertaken mainly after nightfall. If the statements concerning the wanderings of the male are correct, the period of gestation is short, for the young are nearly all born, in this locality, in March and April. It seems more probable, though, that mating takes place in late fall as well as in early spring; perhaps also during milder periods of the winter, as fairly well developed embryos are found in the uteri from January to May. The following table gives the results of some investigations conducted in the spring of 1907 and spring of 1908:

Number of females examined.	Date.	Number of embryos.	Stage of development of embryos, etc.
	1907.		
4..........	Feb. 27	0	No signs of pregnancy.
2..........	Mar. 15	4,5	1 lot nearly fully developed, the other a little less so.
4..........	Mar. 18	5,5,0,0	1 lot only slightly developed; 1 lot about an inch long, thick as one's finger; 1 female evidently pregnant, but fœti not distinguishable; 1 female no signs of pregnancy.
1..........	Mar. 19	0	Uteri congested, but fœti not distinguishable.
2..........	Mar. 25	3,4	1 lot size of thumb; 1 lot size of peanut kernel.
2..........	Mar. 26	1,0	1 lot size of peanut kernel; 1 female gave evidence of having been suckled.
2..........	Apr. 1	3,4	1 lot size of pea; 1 lot size of peanut kernel.
3..........	Apr. 4	4,4,5	2 lots size of end of thumb; 1 lot size of peanut kernel.
3..........	Apr. 5	4,4,5	2 lots size of end of one's finger; 1 lot size of peanut kernel.
1..........	Apr. 8	0	Evidence that young had been born.
3..........	Apr. 9	4,4,4	2 lots fœti in early stages of development; 1 lot size of end of thumb.
3..........	Apr. 15	5,5,0	2 lots fœti size of hulled peanut; no fœti distinguishable in other female.
2..........	Apr. 22	4,4	1 lot size of pea; 1 lot size of hulled peanut.
2..........	Apr. 24	4,3	1 lot in early stage of development; 1 lot size of end of little finger.
2..........	May 3	0,0	Young evidently born; milk in glands of females.
5..........	May 7	3,0,0,0,0	1 lot of fœti size of pea; 2 females showed no signs of pregnancy nor of having had young; 2 females had milk in glands.
10..........	May 13	2,4,0,0,0 0,0,0,0,0	7 females contained no fœti and gave no evidence of suckling young; 1 female had milk in glands; 1 lot of fœti size of pea; 1 lot size of Lima bean.
7..........	May 14	0,0,0,0 0,0,0	No trace of fœti or evidence of suckling young.
10..........	May 20	0,0,0,0,0 0,0,0,0,0	Of the 10 females none carried fœti and only 3 gave evidence of being suckled.
	1908.		
2..........	Jan. 31	0,4	1 female showed no signs of pregnancy; 1 lot of fœti size of peanut kernel.
4..........	Feb. 5	5,0,0,0	1 lot of fœti size of pea; 1 female no traces; 2 females had congested uteri.
5..........	Feb. 7	5,0,0,0,0	1 lot fœti size of peanut kernel; 2 females no traces; 2 females with congested uteri.
3..........	Feb. 8	0,0,0	2 females no traces; 1 female with congested uteri.
9..........	Feb. 10	6,6,5,0,0 0,0,0,0	1 lot size of pea; 1 lot size of peanut kernel; 1 lot size of end of little finger; 2 females no traces; 4 females with congested uteri.
4..........	Feb. 12	4,0,0,0	1 lot size of pea; 1 female no traces; 2 females with congested uteri.

It will be seen that of the ninety-five females examined some showed signs of pregnancy in the latter part of January and all but two or three had given birth to their young before the first week in May. The record for some parts of the season is not so complete, however, as it should be. It should include data for the remainder of January and for the first half of March.

The young are described as being entirely hairless, with transparent skin of a delicate pinky-white. They are blind, their ears are sealed, and in most respects, therefore, they are perfectly helpless. In the fall one may still distinguish the younger specimens by their smaller size, but most of them seem to be fully grown by the advent of cold weather. Long before this time they have excavated burrows of their own and laid up some stores for the winter.

NATURAL FOOD.

The natural food of the pocket gopher consists of the fleshy roots and underground stems of various plants growing wild on the prairies. To this bill of fare he adds occasionally a small quantity of succulent vegetation drawn down into his burrow from the surface at points where exits are dug for removing earth. When foraging thus above ground he loses no time in cramming supplies into his cheek pockets and hurrying below to eat the stuff at his leisure. The underground stems and roots he encounters in extending his burrows are cut into short pieces of convenient length to carry, provided he does not care to dine upon the spot. The sections thus made are commonly an inch or two in length, sometimes shorter, but I have found stores of alfalfa roots in which dozens of the pieces ranged from four to eight inches long. These, of course, the animal must carry or drag to the storeroom without the aid of his pockets. The same is necessarily true of the large cultivated tubers he often steals from the fields or bins of the unlucky farmer. Observations on the habits of a pocket gopher kept in captivity by Doctor Merriam, of Washington, D. C., seemed to indicate that the animal when thus storing his larder can travel as easily and as readily backward as forward. The writer states that the gopher moved back and forth from food supply to storeroom like a shuttle on its track, rarely turning around after securing a load. In its backward progression the sensitive tail served as an organ of touch.

The underground chamber excavated for the purpose of storing food varies in size according to the supplies in sight and the demands of the season. Sometimes one will find only a handful of roots; in other places a peck or more is packed away. Indeed, when an over-industrious gopher finds his way into a pit stored with potatoes or apples he will sometimes carry away and store several bushels of them. A mound of unusually large size is pretty good evidence of the presence of food stores near by, especially if located in the immediate vicinity of a source of plentiful supplies. In some cases a part of the dirt excavated, however, is used to pack the food supplies. I have uncovered stores in which each separate piece of root was carefully separated from the others by fine dirt, much as the farmers sometimes pack sweet potatoes in sand when storing them for winter.

The popular idea that the gopher uses his cheek pockets for carrying out the earth from his burrow is certainly erroneous. I have watched many gophers at work, and noted that the process of removing the earth is always the same: the dirt is pushed ahead of the animal in armfuls. Examination of the pockets of gophers shot in the act of removing earth, or trapped at any time, reveals no traces of contained earth. At this point it might be well to state also that no part of a gopher's runway necessarily extends down to a supply of water, as currently supposed. Like many other animals that feed upon more or less succulent vegetation, sufficient water for the tissues of the body is obtained in the food.

ACTIVE SEASON.

The pocket gopher seems to be busy at any season of the year when the ground is not frozen too hard and too deep for mining operations. Not uncommonly we see mounds of fresh earth thrown up from beneath the snows of midwinter. It is unlikely therefore that, strictly speaking, the animal ever hibernates in this part of the country. During the briefer periods of particularly inclement weather in the winter no mounds are thrown up, and if the animal burrows lower then to escape the frost, as some have observed, he must dispose of the earth in tunnels or pockets previously excavated. It is my belief, however, that the gopher spends these stormy periods near the supplies of stored food. Evidence of this habit is given by certain mounds thrown up in the spring that are made up almost wholly of crumbling pellets of excrement and fragments of nest material. October and November is a season of particular activity. Impelled by the instinct that exacts obedience without forecasting the winter, the gophers then extend their runways in all directions in search of food for their underground cellars. At this time of year the best results can usually be obtained in poisoning or trapping the animals. In the spring, again, after the frost has left the ground, this activity is renewed for a time; but when the season for breeding and rearing the young comes on, extension of the burrows receives less attention.

It has been said that the gopher is a solitary animal; that no two individuals ever occupy the same burrow except in the mating season. This statement is not in accordance with my observations, for I have on several occasions trapped a second gopher by resetting at the same opening into a burrow. This was in the early fall, too; not in the mating season.

NATURAL ENEMIES.

Since the pocket gopher so seldom shows itself outside of its subterranean galleries, it has little to fear from the natural enemies of the rodent race. It is not entirely safe from attack, however, for a few sharp-eyed and vigilant foes habitually capture numbers of gophers when they come to the mouths of their burrows to push out a load of earth. Hawks and owls take toll at these favorable moments, and many a house cat has learned the trick of capturing a meal then with little difficulty.

The gopher's habit of confining active operations in mining mainly to the hours of twilight particularly favors the owl and the cat. The Great Horned owl, the Long-eared owl, and the Barn owl, particularly the last named, render valuable service in keeping down the numbers of these destructive rodents. A single pair of owls, nesting on the farm, has been known to destroy scores of gophers in a brief season. Sometimes they live on nothing else for a time, as evidenced by the pellets of bones and fur which, like most birds of prey, they invariably disgorge after a meal.

Instances of a house cat becoming addicted to the gopher habit are not uncommon. In a number of cases that were reported directly to me, mother cats brought in several gophers a day, regularly as clockwork, to their families of kittens. In many instances of reported gopher catching, however, the informant has had in mind the little striped "gopher" or ground-squirrel.

Two enemies that, in some localities, are said to hold the pocket gopher in check more than all others are the weasel and the bull-snake. The former is too scarce in most parts of Kansas to be worth considering in this relation; but the bull-snake is common enough on farms whose owners or tenants have had the wisdom and forethought to protect the natural enemies of the destructive rodent tribe. The snake would, of course, be able to gain entrance to the gopher's burrow only when the latter was temporarily left open; but once inside he would probably remain there for some time and make things interesting for the occupants. When one is trapping gophers he will occasionally surprise a bull-snake in the act of trying to swallow the captured animal, trap and all. I have also found this snake in the burrow of the striped spermophile, helping himself to a nestful of the young of the latter, and have seen him capture and kill the adult spermophile at the mouth of its burrow.

The little striped skunk (*Spilogale interrupta*) should not be left out of account in discussing the natural enemies of the pocket gopher. I had not supposed that these animals could make their way through the burrows of the gopher, and had laid to the charge of weasels a number of cases of killing and feeding on gophers imprisoned in steel traps. Finally I resorted to setting traps a second time in the mouths of the burrows where a gopher had been partly eaten, and in two instances succeeded in capturing a little striped skunk. There was no question in either case but that the skunk had entered the burrow at some point remote from the location of the trap, for the opening through which the trap had been introduced had been carefully covered with a board and loose earth; this covering was undisturbed. In comparing this slender little skunk's body with the diameter of many of the gopher burrows in alfalfa fields, it will be seen at once that it is not a difficult matter for the skunk to make his way through the underground passages. The additional fact that, by digging, he can enter the burrow at any point and corner the occupant in some lateral or pocket tunnel renders the little striped skunk especially valuable as a gopher catcher.

In summary, it may be said that we cannot, except in a few favored localities, depend upon natural forces to keep in check the increase of the pocket gopher. By increasing the acreage of alfalfa we are producing the very conditions that are favorable to the most rapid multiplication of the species, and, on the other hand, by thoughtlessly or wantonly destroying harmless owls, hawks, bull-snakes, and certain mammals, we still further interfere with nature's efforts to preserve the balance of power in the animal world. The worst that can be said of the enemies of the pocket gopher is that the Great Horned owl, the weasel and the skunk sometimes destroy domestic fowls. But a little wise precaution in shutting up coops at night would prevent these inroads on the poultry industry.

CROPS DAMAGED.

The economic status of the pocket gopher has changed in the last few decades. There was a time when their work was of real benefit to the future interests of agriculture. For untold centuries they have been mixing the soil of the prairies, bringing up the subsoil to mellow, and covering up vegetation to molder and add humus to the clays and sand. But now that the virgin soil has been prepared for us we would gladly dispense with their services, for their presence is now seriously deterimental to our interests.

View of a gopher-infested alfalfa field.

Alfalfa.—The damage to cultivated plants results not only from the animal's eating roots or stems, but also from its habit of throwing up numerous mounds of earth, which very often cover considerable areas of the growing crops and obstruct the harvesting of the remainder later. Indeed, it would scarcely be worth while, in many instances, to make such vigorous warfare on the gopher if the only issue at stake was the kind or quantity of food he pilfered. This is especially true in the case of alfalfa. No other one of the important crops of the state has suffered as much from the ravages of the pocket gopher as this valuable plant. From a gopher's standpoint, conditions of life are easy in a field of alfalfa. The ground is not worked for years at a time, at least not deep enough to interfere with the underground runways. Again, the roots of the plant are fleshy and toothsome and penetrate deep into the soil, where they may be encountered in abundance at the usual depth at which the animal ranges. They are there, too, at any time of the year to satisfy the appetite of the hungry rodent. As a result of these favorable conditions gophers have multiplied at an alarming rate in recent years wherever alfalfa is extensively grown. In the river valleys of central Kansas particularly, I have seen fields of thirty or forty acres in which one might walk over the entire tract by stepping from one gopher mound to another. It is safe to say that in these cases not less than one-fourth to one-third of the actual acreage of the field was covered, and therefore a total loss. Much of that which remained is necessarily weakened by the loss of portions of the root system.

Even a few gophers in an alfalfa field become an intolerable nuisance by obstructing the work of mowing the crop. The man who is running the machine must be constantly on the lookout for the mounds, so that he may raise the sickle-bar until the obstruction is passed. Thus much extra work is entailed and a portion of the crop is lost by running the sickle too high. If the operator does not see the mound in time it is very likely to clog the machine, or at least one or more sections of the sickle may be dulled or nicked by encountering gravel or pebbles. If the ground is reasonably mellow the horses drawing the mower stumble frequently, their feet breaking through into the runways of the gopher. Sometimes the holes thus formed are not filled again from below and the rains washing in enlarge the openings to a pit a foot or more in diameter.

Native Meadows.—Meadows of natural prairie-grasses are often invaded by the gopher to such an extent that they have the appearance of having been plowed up over many acres of their surface. The animals apparently find suitable food scarcer there than in the alfalfa field, and are consequently obliged to dig more extensive runways in search of the roots of the native plants. Unless such tracts of meadow can be freed from the pest and the surface subsequently leveled, they had better be used for pasture, as it is almost impossible to cut the grass for hay.

Orchards and Nurseries.—Young trees in nurseries and orchards or in belts planted for shade, ornament and shelter sometimes suffer seriously from attacks upon their root system. The gopher may gnaw off so many of the roots that the tree readily topples over; or at least it damages the system to the extent that the health of the tree is impaired and its growth stunted. The animal has the habit of following the young hedge or nursery row for some distance, taking everything as it goes. It may then cross over and follow another row in the same manner. Fortunately for the interests of the nurseryman, the gopher never gets the foothold in plantations of young trees that it secures in alfalfa fields, by reason of the fact that the former are cultivated frequently and the ground plowed up every three or four years after the growing stock has been cleaned off. The following are extracts from letters received recently from prominent nurserymen and orchardists of the state:

"There has never been a year since we have planted apple-trees here, thirteen years ago, that we have not been troubled with gophers. They eat the roots of the large trees. Have never noticed that they went straight down the rows."—E. E. YAGGY, Hutchinson.

"Once I had a large Austrian pine (seven feet) gnawed off at the surface, and in a few hours afterwards the tree fell. I shot the gopher and planted another pine in its place."—H. F. CECIL, Topeka.

"The gophers have been a serious pest to nurseries or trees near grass or clover. They will sometimes go a long way through the trees if not checked. They eat any kind of wood, even the hard Osage hedge. I do not remember that they have ever eaten any grape-vines for me, but probably because they are not where they could get to them freely."—A. H. GRIESA, Lawrence.

"Will say, in regard to the pocket gopher, that we are not troubled as much now as we were a number of years ago. When we first commenced planting trees in this locality we had considerable loss from them. They do not seem to be particular as to the kind of tree. As we grew more apple-trees than anything else, our loss was heavy in that line. We found that the best manner of ridding ourselves of the gopher was to poison them."—J. H. SKINNER, Topeka.

"We have had considerable trouble with the pocket gopher and a great deal of loss. They seem to be worst with our young cherry. They sometimes run along the row for a few trees and then cross over into another row. They do not often kill more than from six to ten in one spot."—A. L. Brooke, Topeka.

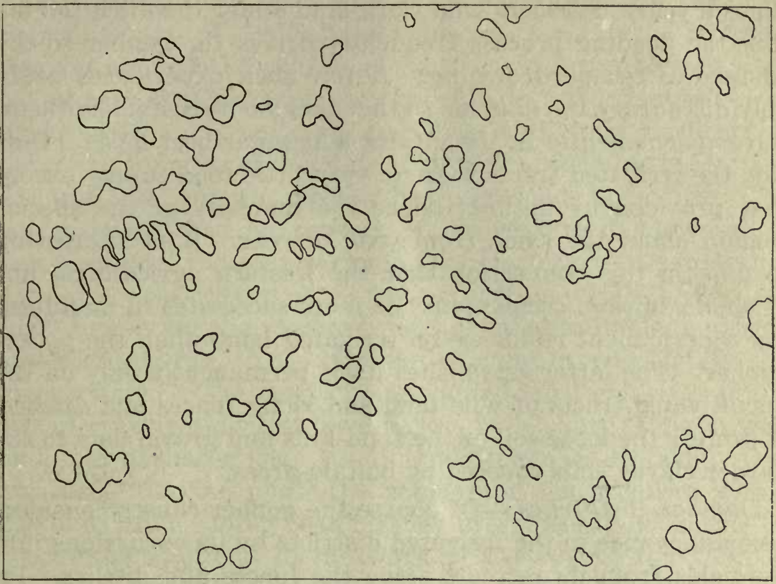
"The pocket gopher is not a great pest with us, yet does considerable damage. He does not seem to be particular as to what he destroys. The past season he has crossed a block of two-year-old cherry-trees, taking one to three trees in a row and crossing over half the block. In one place he has cut off probably fifty pear trees (Kieffer), and in still another place a half dozen poplars, ten feet high, an inch in diameter. We like to follow with trees where alfalfa has been plowed up, but it is nearly impossible to do so on account of pocket gophers. They seem to congregate in the alfalfa, and it takes a year or two to get the land free from them."—F. W. Watson, Topeka.

Potatoes.—Potatoes and sweet potatoes sometimes suffer seriously from the depredations of gophers, but of course the animals do not gain a permanent foothold in potato fields as they do in the tracts of ground remaining uncultivated for a period of years. They generally invade the potato ground from the surrounding fence-rows or from adjoining meadows or alfalfa fields. If no effort is made to destroy them, they will often establish themselves for a time in any part of the cultivated field. Here they eat the pieces of potato that are planted in the spring or bite off the roots of the young sweet potato plants. Later they feed upon the newly forming roots or tubers, causing the death of the plant. In the fall they proceed to harvest their share of the crop and store it in their underground root-cellars for winter use. Not content with what they may harvest on their own account, they find their way into the farmer's potato-pit and steal at their leisure. It is surprising to note the heaps of potatoes, sweet potatoes and apples sometimes carried away thus from pits and cellars and stored in chambers in the gopher's runways. In making inquiries of potato growers along the Kansas valley I have learned of several instances where the thefts amounted to five or six bushels. Prof. L. L. Dyche, writing to the Department of Agriculture, reports a case near Lawrence in which thirty-five bushels of sweet potatoes were taken from a cellar dug in rather sandy ground. To make room for their stolen treasures the rodents carry all the excavated earth into the potato cellar and pack it from time to time into the space left vacant by the removal of the tubers. The farmer, therefore, rarely learns of the loss he has sustained until he removes the contents of the cellar in the spring, when he is astonished to find, some distance below the surface, a huge pile of earth where there should be potatoes or apples. No caving in of the heap in the cellar, no piles of earth on the surface of the ground, have betrayed the gopher's work, which may have been in progress for weeks or months. By making a vigorous search the farmer sometimes recovers a part of his property, however, for the gopher's avarice has prompted him to carry away vastly more than he can possibly ever hope to eat. In the case mentioned above but two gophers could be found to answer to the charge of stealing thirty-five bushels.

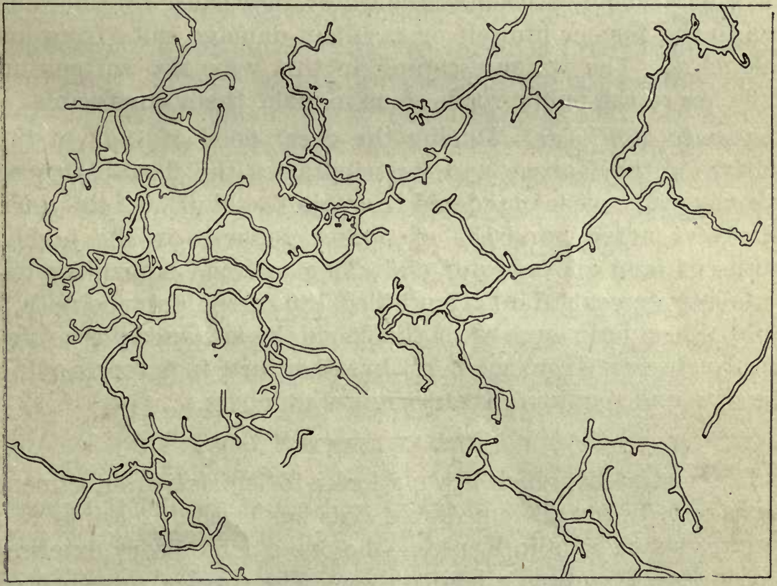
Garden Crops.—There are very few garden crops but that receive occasional attention from the pocket gopher. He does not even draw the line at the odoriferous onion, but prefers, of course, the fleshy roots, such as beet, parsnip, carrot and turnip. He is also said to have a habit of gnawing into the under side of melons and pumpkins and hollowing out the interior, sometimes filling the cavity thus formed by packing it with earth. I have not been able to verify this statement. Peanut growers suffer some loss from the depredations of pocket gophers. One correspondent, writing to the Department of Agriculture from Reeder, Kan., states that twenty-five bushels were taken from the crop grown on an acre of ground.

Small Grains.—Apparently no serious loss results from the work of pocket gophers in fields of small grain. The roots of such plants are not large enough to attract the animals. Sometimes, though, they bite off and drag stems and heads into their burrows below. When grain is in the shock, too, they often come up from beneath and carry down the heads, filling in the spaces between the sheaves with dirt. It is not fair to lay all such work to their charge, however, for they are assisted by field-mice, spermophiles and the common rat.

Irrigated Crops.—Contrary to my expectations, I did not find the gopher a serious problem in the irrigated districts of the southwestern part of the state. The prairie gopher (*Geomys bursarius*) of eastern and central Kansas is there largely replaced by the plains gopher (*Geomys lutescens*). I scarcely think the latter is as aggressive in its habits as the former; at least it has not gained much of a foothold in the extensive fields of alfalfa that have been grown in that section for years. On the other hand, this may be partly or wholly due to the flooding of the fields from the irrigating ditches several



Typical area of a badly infested alfalfa field. This tract (54 ft. x 72 ft.) was carefully mapped after first dividing it into small squares by tightly stretched lines. The small irregular patches show the shape, relative size and location of the mounds thrown up by the gophers.



Same tract as above, with all the runways carefully excavated and mapped.

times a year. Farmers who work land under the ditch tell me that the flooding process frequently drives the gopher to the surface to escape drowning. A few such experiences probably discourage the animals so that they do not establish themselves permanently in the alfalfa and sugar-beet fields. Outside the irrigated tracts there is very little food supply except that provided by nature; hence the numbers of the species remain about the same from year to year. It is interesting to note in this connection that the western agricultural ant (*Pogonomyrmex occidentalis*) is more successful in maintaining a permanent residence on irrigated lands than the pocket gopher. The latter establishes itself permanently only on the uncultivated tracts of wild land and along fences and ditches. It prefers the loose soil of the sand-hills and gravel flats to the harder clayey soils covered by buffalo-grass.

Damage to Ditches.—Of course the gopher causes considerable annoyance in the irrigated districts by its excursions into the fields from its retreats along the fences and ditches. Its habit of burrowing into the banks of the ditches is most exasperating to the farmer who, when he turns the water on, must often spend hours locating and stopping leaks. These leaks, enlarged by erosion of the water, may cause considerable loss to the farmer himself or result in damage suits from his neighbors. The water escaping in this way also softens up stretches of the public roads so as to make them impassable.

Results of Floods.—During the great flood of 1903 in the valleys of the Kansas and its tributaries the flood-plains of many streams were inundated from bluff to bluff. At this time observers noted hundreds of pocket gophers on the higher points of land above water and along railroad embankments. An observer near Manhattan killed 180 of the animals with a club. For a year or so after the floods the lowlands were comparatively free from gophers, but they are fast reoccupying the flats and regaining their original numbers.

GOPHER LEGISLATION.

The sentiment which always looks to legislative enactment for a remedy for all remediable evils has crystallized into two recent gopher laws in Kansas—the one a compulsory extermination law, the other a bounty law. The former was enacted by the session of 1905; the latter is a part of the grist from the mill of our last legislature in its regular session.

The compulsory extermination law—House bill No. 184, Session Laws of 1905—might be made a pretty effective weapon against the pocket gopher, but unfortunately it does not appear that township officers care to avail themselves of its provisions. From correspondence with county officers in nearly all counties of the state, I have not been able to learn of a single case wherein the law has been made operative. The law provides that, on petition of ten resident landowners of any township, the county commissioners may, at their discretion, direct the trustee of the township from which the petition came to appoint the road-overseer, or other suitable person in any road district, to see that the gophers in said district are exterminated. The person so appointed must enter the premises of every resident of his district at least three times a year on a tour of inspection. If any landowner fails to take proper measures to exterminate the gophers on his premises within five days after having been notified in writing to do so, the inspector must attend to the work of destroying the animals. The costs are then charged up in the taxes of the delinquent landowner. Other expenses incurred in the work, including a salary of two dollars per day for the inspector, are paid out of the general fund of the township. A weak point in this law is the clause which leaves it optional with the commissioners to authorize the appointment prayed for or to ignore the petition altogether. Then, too, the provisions of the law make it necessary for one neighbor to interfere in affairs that may seem to another clearly none of the former's business. He may reason that pocket gophers, because of their burrowing habits, are like weeds, practically fixtures of the soil, to be eradicated or allowed to thrive as the owner of the land pleases.

The new bounty law* requires all counties in the state to pay a premium of ten cents per head on pocket gophers. This law will probably result in a considerable diminution of the pest in some localities. The bounty system in general, however has its objectionable features, and in the particular case of the animal under discussion these features are prominent. In the first place, the gopher roams about so little above ground that each individual is practically a permanent resident of the farm on which its burrow is located. The justification for placing a price on the scalp of an animal like the coyote or puma, that may take toll from one man's flock to-day and from his neighbor's, miles away, to-morrow, is entirely wanting in the case of the pocket gopher. The principle of allowing the community at large to pay the expense of protecting the careless man's crop, while his thrifty neighbor looks after his own fields, is theoretically wrong. It imposes a double burden upon thrift.

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* The attorney-general of Kansas having rendered a decision which practically invalidates the state bounty law, several counties east of the sixth principal meridian are now paying bounty under the old law of 1903.

Again, the payment of ten cents for each scalp will put a premium on trapping and tend to discourage poisoning, the more thorough and easily applied method of ridding a badly infested locality of these pests.

Further, the expense of maintaining a bounty system is usually out of all proportion to the benefits gained. Experience in other states, and in a few counties in this state, has demonstrated that bounties on small mammals seldom, if ever, accomplish the desired end—ridding the community of the pests. After the cream of the territory has been skimmed, so to speak, trapping becomes unprofitable and large numbers of the animals are left to again regain their ground. Long before even the skimming process is completed, however, the heavy drain on the public treasuries usually results in the repeal of the law. No state has ever been able to pay a general bounty on small mammals for any considerable length of time.

Finally, the opportunities for fraud in the matter of claiming bounties are much greater in the case of the pocket gopher than with the larger and better known mammals. The majority of county clerks to whom the scalps will be presented have perhaps never seen a pocket gopher. At least they are not trained mammalogists, and only such can, under certain circumstances, distinguish the scalp of a pocket gopher from that of some of the other small mammals. The law requires that the scalp, with the ears, be presented in evidence; but the gopher has practically no external ears. Any ingenious boy with a ticket punch can easily manufacture a half dozen legal scalps from the pelt of a single gopher. Although not specified in the law, it would be well to require the cheek-pockets to be included with the scalp. There could then be little question as to the identity of the animal.

In 1903, four years previous to the enactment of the present bounty law, an act was passed authorizing county commissioners, in their discretion, to pay a premium of five to twenty-five cents apiece for the scalps of pocket gophers and gray ground-squirrels. The scope of this law was limited, by provision, to counties east of the sixth principal meridian. Under this act eight counties have paid premiums on gopher scalps for periods ranging from three months to four years. The list of these counties follows: Atchison, Brown, Jefferson, Johnson, Leavenworth, Marshall, Morris, and Pottawatomie. Some of them report the payment of only a few dollars per year in bounties, while in other cases the amounts are considerable. Leavenworth county, for example, paid out $2480, after which the commissioners withdrew the bounty. Marshall county has just withdrawn its bounty, after paying out in the year 1907 $4200. Township trustees from all parts of the county report that the numbers of pocket gophers are apparently as great in their respective townships as they were when they began paying bounty a year ago. Evidently the trap is slower than the gopher's rate of increase. Wholesale fraud in the matter of manufacturing several scalps from one skin is suspected in a number of cases.

If a few farmer boys in every school district in certain counties of central Kansas should become as active in the extermination of the pocket gopher as the law perhaps contemplates, those counties would soon be stamping their warrants "Not paid for lack of funds." By way of supporting this statement, let me cite two illustrations: Benton county, Iowa, paid out in three years $18,000 in bounty on gophers, at an average rate of fourteen cents per scalp. Meeker county, Minnesota, withdrew its bounty on pocket and striped gophers, or ground-squirrels, after having cashed bounty warrants to the amount of $14,056 in five months.

If the destruction of the pests is to be paid for out of the public treasury, better results can be obtained, and at a much less cost, by the plan of distributing a prepared poison free to those landowners who will agree to use it as directed. Counties that have tried this plan in other states prefer it to the bounty system. Why may we not profit also by our own experience in ridding western Kansas of the prairie-dog? Under the provisions of an act passed by the legislature of Kansas in 1903 the purchase and use of poison in all townships infested by prairie-dogs was made compulsory. All expenses were defrayed from the township treasury, the county commissioners having previously made a special levy for the purpose. The vigorous campaign that followed the enactment of this law almost wiped the prairie-dog from the face of the land. A reenactment, therefore, of the prairie-dog law of 1903, so modified as to fit the case of the pocket gopher, is, in our opinion, the wisest measure that could be adopted.

Even though we do not get a compulsory "extermination" law for the pocket gopher, the thrifty farmer would profit much by legal enactment compelling road-overseers to keep down the pest on the roadsides. The same should apply also to the foremen having charge of the various sections on the railroad right of way. It is a matter of common observation that when gophers invade a clean field they usually enter from the roadsides, railroad right of way, or neglected fence-row.

METHODS OF COMBATING.

Poisoning.—Gophers do not possess the shrewdness and cunning that have become instinctive in many other wild creatures because of the constant necessity imposed upon the latter of avoiding and escaping enemies. Later experience in the wiles of man has evidently taught them nothing, for they seldom reject any kind of poisoned food offered them.

As stated before, poisoning is the more thorough and easily applied method of ridding a badly infested farm of the pest. It is also the best method if the territory to be freed from gophers is of considerable extent. In either of the above cases one man can accomplish as much with poisoned bait as a half dozen could in the same time with traps. The danger of killing stock or useful birds and animals, attending the use of poison for prairie-dogs, English sparrows, and the like, is entirely eliminated by the plan of introducing the bait through small openings into the gophers' burrows.

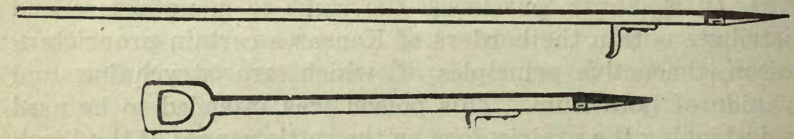
Since the pocket gopher lives naturally on the roots and tubers of native plants, or on succulent vegetation drawn down into the burrow from the surface, it follows that a close substitute for these articles will make the best bait for poisoning. Knowledge gained by personal experiments and by careful inquiry among farmers and fruit growers goes to show that pieces of potato, apple, or sweet potato, poisoned by inserting a few crystals of strychnine into slits made with the point of a knife, answer the purpose very well. Some correspondents have reported good results from soaking the baits in a solution of arsenic or strychnine. Only a mechanical mixture of either substance can be obtained in water, however, and the presence of particles of the free poison on the surface of the bait would be more likely to cause its rejection than if they were concealed in small slits. Raisins and prunes, treated like the pieces of potato or apple, seem to be very effective baits also. Our experience with specially prepared tablets, sold under patented formulas, does not warrant us in recommending them.

There is some question as to the efficacy of any sort of scent applied to the poisoned bait. We have tried scented and unscented bait at the Station without being able to determine that one was eaten more readily than the other. All claims to superiority in certain proprietary gopher poisons, based on the use of a secret scent, may be set down as lacking the warrant of practical test. It is true that the sense of smell is probably highly developed in the pocket gopher, owing to the necessities of his underground life, but we lack evidence as to what may appeal to his tastes. Anise oil is often put on baits for various animals, but in poisoning gophers as good results are obtainable without its use.

About five years ago the state, through a special agent, Prof. D. E. Lantz, purchased the right to manufacture and distribute within the borders of Kansas a certain proprietary poison, the active principles of which are strychnine and cyanide of potassium. This poison was intended to be used in destroying the prairie-dogs on the cattle ranges of the West, but it was found that by leaving out one ingredient—the cyanide of potassium—a very efficient poison for pocket gophers could be prepared. After the state's contract with the special agent had expired by time limit, the work of manufacturing and distributing this poison was turned over to the Department of Zoölogy and Entomology in the College. The poison is put up in the form of a syrup and sent out in quart cans to any part of the state. On each can is a printed label giving the formula used in preparing the poison and full directions for its use. The success attending the use of this syrup is evidenced by the fact that in the past four years we have sent out over 1500 cans. Experiments personally conducted on the Station grounds and elsewhere have borne out the uniformly favorable reports from alfalfa growers, particularly, as to the merits of the poison. We therefore recommend this poisoned syrup as the best means we have discovered so far for the destruction of pocket gophers. The syrup is sold by the College at actual cost of manufacture, which at present is $1.10 per quart can.

The method of using this poison commends itself as a time saver. Pour boiling water over as much shelled corn as you will need—the quart of syrup will poison a half bushel—and let it stand several hours to swell and soften. Drain off the water and pour over the grain enough of the syrup to render it sticky when thoroughly stirred together. Sweeten the mass with a little good table syrup and add a little corn-meal to take up the excess moisture, but not enough to leave any dry meal. Cork up the syrup can tightly and place it out of reach of children and domestic animals. It will keep indefinitely and is ready for use at any time.

The soaked corn, poisoned as above, is introduced into the burrows of the gophers, a few grains at a place, by means of an old spoon. Openings into the burrows must first be made with a sharp stick—a sharpened broom handle will serve the purpose—or a spade handle shod with an iron point and having an iron foot-bar some distance from the end to aid in making the thrust. Experience will soon enable one to tell when he has struck the burrow, which can be located approximately by getting on a line between two mounds of earth. After dropping in the poisoned grain the hole may be left open, or if closed care should be taken not to allow dirt to fall in and cover up the bait. If the hole is left open the gopher is likely to be attracted by the light and find the bait the sooner.



Two forms of prod for locating runways of the pocket gopher and making openings for the introduction of poisoned bait.

The same method of introducing the poison into the burrows is employed also when raisins and prunes or pieces of apple and potato are used. The presence of freshly thrown up mounds indicates that the animal is extending his runways in that quarter, and it is best to confine one's poisoning operations to such places. If the field can be dragged over with a harrow or plank a few days after the poison has been put out, new mounds can be readily detected and fresh poison distributed. If the work was thoroughly done in the first place it usually takes but a few minutes to go over the field a second time. The few remaining gophers, if any, may become wary, and in that case they should be trapped.

The best time of the year to poison gophers is when they are most active in extending their burrows. This is usually in the late fall, for they are then laying in stores of provisions for the winter. Spring is a period of renewed activity, and poison may be successfully used at this time also. In fact, it will pay to make war on pocket gophers at any time when they are seen to be active.

Fumigation.—The use of carbon-bisulfid vapor or the fumes of burning sulfur as agents for destroying the pocket gopher is not recommended by this Station. It is true that fumigation methods are occasionally followed by successful results, but under ordinary conditions the game is not worth the powder. We have other remedies for the pest that can be more easily, more effectively and more cheaply employed. An older bulletin of the United States Department of Agriculture recommends carbon-bisulfid as the simplest agent for the destruction of gophers, but later advices from the same source partially discredit the former recommendations, and experiments at this Station contribute to the same result.

The ordinary method of using carbon-bisulfid for destroying burrowing rodents is to pour the liquid upon a wad of cotton, corn-cob, or other porous substance and then thrust the latter into an opening made into the burrow, closing the opening at once with earth. The bisulfid vaporizes rapidly, forming a heavy gas which is supposed to flow along the runways, smothering the occupants. This it will do in the case of animals whose burrows are short or penetrate deep into the soil. The pocket gopher, however, in his search for food ranges so near the surface of the ground that the introduced gas has plenty of opportunity to escape through the loose earth or to be absorbed. The burrows are long and intricate, branching often and in places reaching almost the actual surface, especially where the excavated earth has been thrust out or where the animal has started to dig an exit and later abandoned the work. If the ground is dry the gas is dissipated the more rapidly, so that good results might be expected only when the soil is sodden by recent rains.

With us, the plan of forcing the gas into the burrows by means of a bellows gave no better results than the methods described above. The apparatus used for forcing the gas consisted of an ordinary two-gallon kerosene can with a ten-inch hand-bellows connected by a short piece of half-inch hose to the opening at the top of the can. This end of the hose, or a tin tube attached to it, should extend nearly to the bottom of the can, so that the air from the bellows will have to bubble up through the liquid bisulfid on its way to the exit at the spout. The vapor thus formed is led into the burrow by means of another short piece of hose attached to the spout of the can. I have described the apparatus here because some who have used it in localities where there were comparatively few gophers and the burrows simple, claim that they have rid their farms of the pest by this means.

In order to give the gas-pumping method a thorough test, a larger quantity of bisulfid was used in repeated experiments than has been recommended when the liquid is simply to be introduced on a wad of cotton. At each opening made into a burrow the bellows was operated four or five minutes, vaporizing from four to seven ounces of carbon-bisulfid. This variation in the amount of liquid vaporized in equal periods of time was due to difference of quantity put into the can before the series of experiments was begun. The larger the quantity the more gas will be evaporated in a given period. As carbon-bisulfid costs about twenty cents per pound retail, the expense of treating each burrow was therefore from five to eight cents, not counting the time of the operator. A very conservative estimate will place the average cost of attempting to destroy pocket gophers by this method in the alfalfa fields and meadows of central Kansas at one dollar per acre for materials alone. Results do not justify this expense. In a series of thirty experiments personally supervised by the writer during the fall of 1906 and spring of 1907 but four were attended with successful outcome, three of these at a time when the ground was fairly well soaked by recent rains. The method of determining results in all cases was to open the burrow some hours after the introduction of the gas and then visit the spot a little later to note whether the opening had been closed. As indicated above, in twenty-six out of thirty cases it was found that fresh dirt had been pushed into the opening, showing that the occupant of the burrow was uninjured. In a series of experiments conducted recently at Alden, Kan., with the plains pocket gopher, ten out of twelve openings were promptly closed after the burrows had been thoroughly fumigated.

In one experiment, undertaken with particular care, a line of mounds on a gentle slope of prairie sod was selected as indicating a single, simple burrow. At a point 100 feet down the slope from the last mound in the line an opening was made into the runway and the latter sufficiently enlarged to receive a cat. In four minutes from the time the operator began pumping gas at a second opening—100 feet distant—the cat yielded its nine lives separately and individually to the cause of science. Not so the gopher, however. After pumping gas into two openings made below the point where the cat had been placed, the field was abandoned until the next day, when it was found that the gopher, or gophers, had packed some of the openings and were defiantly throwing up fresh mounds.

No experiments in forcing fumes of burning sulfur into the burrows were undertaken, but in a number of the trials mentioned above the charge of carbon-bisulfid vapor was exploded by dropping a lighted match into the opening of the burrow after removing the can to a safe distance. The gas resulting from the combustion of the carbon-bisulfid vapor is the same as that produced by burning sulfur—sulfur dioxid. Although no disaster to the gopher seemed to follow these explosions, the distance to which the gas had penetrated and the length and intricacies of the burrows was demonstrated by the presence of smoke or loose earth forced out at weak places.

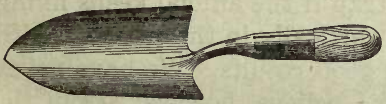
In the case of the experiment with the cat, cited above, the investigator who furnished the apparatus for the trial undertook to increase the efficiency of the gas by adding flowers of sulfur to the liquid in the can. This served only to clog the machine, however, as none of the sulfur can be dissolved in the carbon-bisulfid. A certain manufacturer of a proprietary liquid for destroying pocket gophers by fumigation claims that he has added something which will increase the volume of gas arising from the bisulfid. More attention might be paid to his claim if efficiency depended upon volume alone.

Trapping.—Although somewhat slow, there is no surer method of ridding one's premises of pocket gophers than by trapping. When you have the animal fast in the jaws of a trap you are certain that his career of uselessness is over. If the gopher were as wise as a rat we would not be permitted to indulge this feeling very often, but a long series of experiments has convinced me that he will blunder into almost any sort of trap that is set for him, no matter how we set it. Long experience in the wiles of man, as a result of living in the nooks and corners of his habitations, has developed by natural selection a race of rats that is proverbial for sagacity. Such shrewdness the pocket gopher will never know, at least not until after many generations of contact with his sworn enemy, man. On the other hand, it is true that a "burned child dreads the fire," and after a gopher has once been nipped by a trap that failed to hold him he becomes more or less wary, and the trap must be set in a different way or poison must be employed to get him.

As stated elesewhere, trapping is a good method of combating gophers if the field to be cleared of the pest is small or if over a large area there are but a few scattered gopher tenants. If the landowner is vigilant, the career of any invader may with little trouble be ended by the use of the trap. The objections to trapping are that it is slower than poisoning and more expensive, particularly the latter if one must hire somebody to do the work. While I have elsewhere in this bulletin presented objections to the bounty system as a public measure, I believe that money paid for gopher scalps by individual landowners is wisely expended. Give your boys or your neighbor's boys a chance to earn a little pocket money, and thus by expending dimes save dollars on your crops. Furthermore, as the number of gophers on your place diminishes raise the price per scalp now and then, so that the boys may be encouraged to complete the extermination. This is strictly a business proposition. No busy farmer need give much of his time to the work, but he will find that the average boy will get as much satisfaction out of earning money by trapping wild animals as he will from expending the same in the various channels known only to his tribe. Then, too, the farmer will have the satisfaction of knowing that the expense of freeing his premises of the pest has not been borne by the public treasury.

In the course of our experiments, covering a period of three seasons, several makes of special gopher traps have been thoroughly tested for efficiency, and the ordinary steel trap has been set in various ways with the hope of finding a best way. In the latter respect I cannot say that we have succeeded, for it does not seem to make much difference how one sets the steel trap; results will be about the same. These results, obtained by 100 tests of each of four or five different methods, are given in the table further on.

In trapping the location of the runway is determined in one of two ways: by prodding with a sharp stick on a line between two fresh hills of earth, or by digging into the mound itself until one strikes the short lateral. A sharpened broomstick, or a wagon rod, and a spade, are the best tools to use if one follows the first plan. In digging into the mound to the lateral a heavy plant trowel, with a strong shank, serves the purpose very well, and can be carried about in the hip pocket when not in use. A careful scrutiny of the mound will usually reveal the exact spot from which the dirt was thrown out and enable one to locate the lateral with very little digging.



A handy tool for use in setting traps.

Among the methods of setting the steel trap which suggested themselves to us, or were recommended by others, we tested five. As stated before, the per cent. of catch did not vary greatly. The plan of digging into the lateral at the mound, pushing the trap back a little way and leaving everything open gave the poorest results. More of these traps were packed with earth and fewer caught and held the gopher than when set in any other way. Attracted by the flood of light which enters the burrow at the large opening the animal is pretty sure to come pushing a heavy load of dirt ahead of him. This clogs the trap at once. The plan of admitting a little light through a chink between the sods covering the opening into the burrow, or through a hole bored for that purpose in a board, demonstrated that the admission of any light at all is unnecessary and perhaps operates to reduce the catch. The gopher is not so likely to be pushing a load of dirt when he encounters the steel trap in the dark. As between covering the trap itself or leaving it uncovered, I should recommend the latter plan. In a series of 100 tests we carefully covered one trap in each case with tissue paper and fine earth and left the other exposed. The per cent. of catch was so nearly the same that the slight difference in favor of the covered trap would not warrant the expense of extra time required to set the traps in this way. In fact, later experiments, performed when the ground was wet from recent rains, gave the poorer results for the covered trap, on account of the jaws clogging. As the gopher in his underground tunnels must be guided entirely by the sense of smell and of feeling, there could be no particular advantage in concealing the trap with a thin covering of earth. This practice has no doubt arisen from similar methods employed in trapping animals that live above ground.

It seems to me, therefore, that the most practical and efficient method of using the steel trap is to simply open the burrow at some point, introduce the trap and completely cover the opening you make with sods, a bunch of hay, or perhaps a board—anything that is convenient and will exclude all light. Vary the method of setting the trap if the animal keeps filling it with earth. Placing the trap vertically in the runway, with jaws down, will sometimes give good results. We have never tried baited traps of any sort. I believe, however, from the evidence of a few experiments, that one may increase the per cent. of catch by covering the opening above the trap with freshly cut alfalfa.

Traps designed especially for the pocket gopher have the advantage, over the steel trap, of being more easily and quickly set and of killing the animals at once instead of holding them by the leg for hours. Some of them also have given us a higher per cent. of catch than the steel trap. Of the five different patterns we have tested, all are built on pretty much the same lines. They are intended to be set at the end of a lateral, and are so constructed as to throw when the gopher pushes a load of earth against the trigger. A choker or a pair of sharp prongs does the rest. In setting any of these traps a ray of light must be admitted to the burrow through a small opening, so as to attract the attention of the gopher and cause him to come with a load of earth to stop up the hole. The trigger in any such special trap should be about three inches beyond the choker, so that when the former is tripped by pressure of the earth the animal will have his neck well in the noose.

The "California" gopher trap and the "O. K." gopher trap are almost identical in appearance and design. Both are easily and quickly set, and good results are obtainable by the use of either one. Each consists of a small box with one end open for the entrance of the gopher's head. At the opposite end of the box a small hole is bored to admit a ray of light. The box, when the trap is set, practically forms a continuation of the burrow. It should be placed with the open end close up to the opening into the lateral and the line of contact between trap and lateral sealed with a few handfuls of earth so that no light may reach the burrow except through the small hole in the end of the box. The trigger is skeleton in form so as not to obstruct this light, and depends vertically from the center of the box.

The "Out O' Sight" gopher trap is built like the "California," except that the sides and end of the box have been omitted—simply the roof is left for the attachment of the working parts. This trap is to be set in the same manner as the two just described, but one end has to be supported by means of a small stick laid across the opening into the burrow and sods must be used to exclude all light, except the ray which is to attract the attention of the gopher. Plainly the disadvantage in the use of this trap is in the greater length of time required to set it.

The "Newhouse" gopher trap is entirely of steel. It is arranged to trip in the same way as the other, but instead of a choker it has three sharp prongs which strike down into the neck of the animal. It is the least efficient of all of the makes of special gopher traps we have tried. If properly set it must be supported by a stick at one end, and so covered by sods as to leave only a small chink open. It is so light that a gopher coming with his load will upset it oftener than spring it. The small size of the trap also permits it to be drawn back into the burrow if the animal is caught. In this way we lost half of our traps the first week of our experiments. If used at all they should be secured with chain and stake. A few experiments seem to indicate that this trap gives much better results when used in the smaller burrows of the plains pocket gopher.

The best time to trap is in the spring and fall, particularly

STEEL TRAP TESTS.

Conditions under which traps were set.	Number traps set.	Number disturbed.	Number gophers caught.	Per cent. catch.
Entrance to burrow entirely darkened; trap covered with tissue paper and fine earth	100	77	28	36+
Entrance to burrow entirely darkened; trap left uncovered	100	75	25	33+
Entrance to burrow left wide open; trap not covered.	100	81	17	21
Entrance to burrow covered by board having a small hole for the admission of light; trap not covered	100	66	18	27+

In all cases the light No. O steel traps were used. They were placed horizontally in the runways and were not baited. The per cent. catch is based on the number of traps disturbed, including those that caught and held the gopher. The tests were made mainly in the spring and fall months in October and November. At those seasons the gophers are especially active in extending their burrows or storing up food. It will generally pay to run the traps twice a day—in the morning and as late as practicable in the evening. Experience has proven that one may sometimes catch a second gopher by resetting at the same opening where one has already been trapped, but is scarcely worth while to make the attempt unless one notices after trapping the first animal that the opening into the burrow has been filled again from the inside.

SPECIAL TRAP TESTS.

Trade name of trap.	Number traps set.	Number disturbed.	Number gophers caught.	Per cent. catch.
California Gopher Trap	100	71	26	36+
Newhouse Gopher Trap	100	72	14	19+
Out O' Sight Gopher Trap	100	82	36	43+
Newhouse trap modified by addition of sheet-iron shield and skeleton trigger	100	69	26	37+
Ordinary steel trap set various ways	100	75	23	30+

Shooting and Trap Guns.—If one has the time and inclination to do a little shooting, he can kill quite a few gophers with the shotgun. The best time for shooting is early in the morning or late in the evening, when the animals are pushing out their loads of earth. Open holes can then usually be found, but if not one can easily open a few burrows and keep watch of those which are being filled up again. It requires quick work on the part of the sportsman to bag his game, for all that can usually be seen is a little spurt of earth and perhaps a nose. In a few cases that came under my notice a bag of ten or a dozen gophers was made in a single evening or morning.

A trap gun so arranged as to be discharged by the act of the gopher in pushing against an obstruction in his burrow has been recommended by at least two of the experiment stations. The objection to this recommendation lies in the first cost of the mechanism and the amount of time required to visit and reset the gun each time it has been discharged.

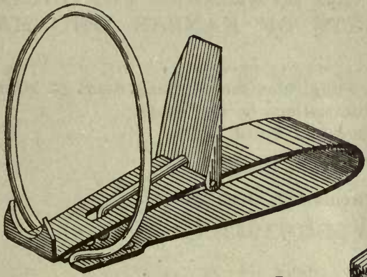


Fig. 1.

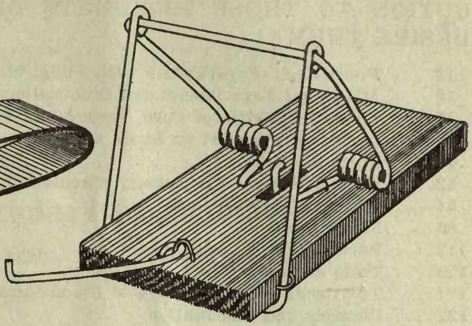


Fig. 2.

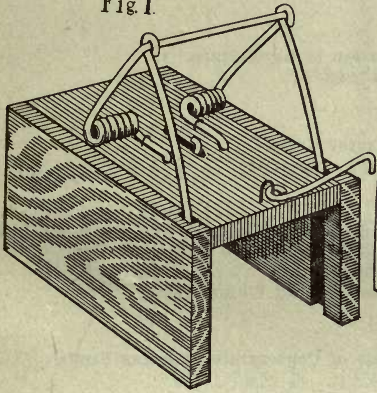


Fig. 3.

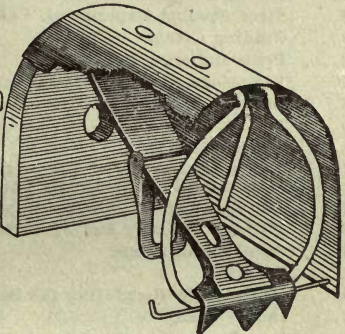


Fig. 4.

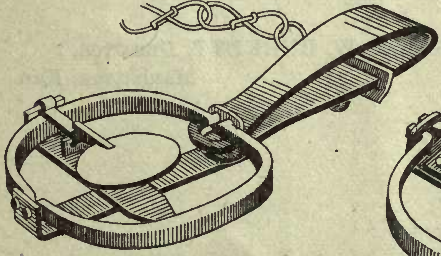


Fig. 5.

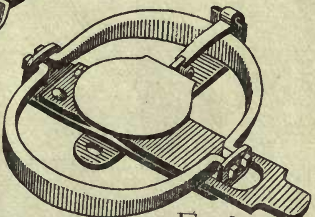


Fig. 6.

Fig. 1, Newhouse gopher trap. Fig. 2, Out O' Sight gopher trap. Fig. 3, California gopher trap. Fig. 4, Newhouse trap as modified for use at this Station. Fig 5, steel trap No. 0. Fig. 6, the steel jump trap.

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Kansas State Agricultural College.

EXPERIMENT STATION.—Bulletin 161.

ED. H. WEBSTER, *Director.*

TECHNICAL BULLETIN.

Bacteriology Department.

WALTER E. KING, *Bacteriologist in Charge.*

THE INFLUENCE OF DEPTH OF CULTIVATION UPON SOIL BACTERIA AND THEIR ACTIVITIES.

BY

WALTER E. KING, *Bacteriologist.*
CHARLES J. T. DORYLAND, *Assistant in Soils.*

MANHATTAN, KANSAS,
AUGUST 12, 1909.
8—391

Kansas State Agricultural College Experiment Station.

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The Influence of Depth of Cultivation upon Soil Bacteria and Their Activities.

By

WALTER E. KING, *Bacteriologist.*
CHARLES J. T. DORYLAND, Assistant in Soils.

INTRODUCTION.

THERE are those who believe that future work in soil bacteriology will have considerable bearing upon the problem of maintaining soil fertility. This belief is founded upon the existing knowledge of soil bacteria, and the suggested part that bacterial action plays in preparing the soil for plant growth.

Granting that our present rather limited knowledge portends to show that soil bacteria and their activities are useful and essential attributes of fertile soil, it seems justifiable that attempts should be made to determine the influence of different conditions upon the number and specific activities of the bacteria living in various types of soil.

The consideration of the influence of depth of cultivation upon the soil bacteria and their activities is a broad subject, which embraces a host of minor problems. The whole problem can be determined only by an immense amount of experimental work and years of patient labor. The experiments outlined in the following pages, therefore, must be considered as preliminary and the suggested results as only forerunners of definite conclusions.

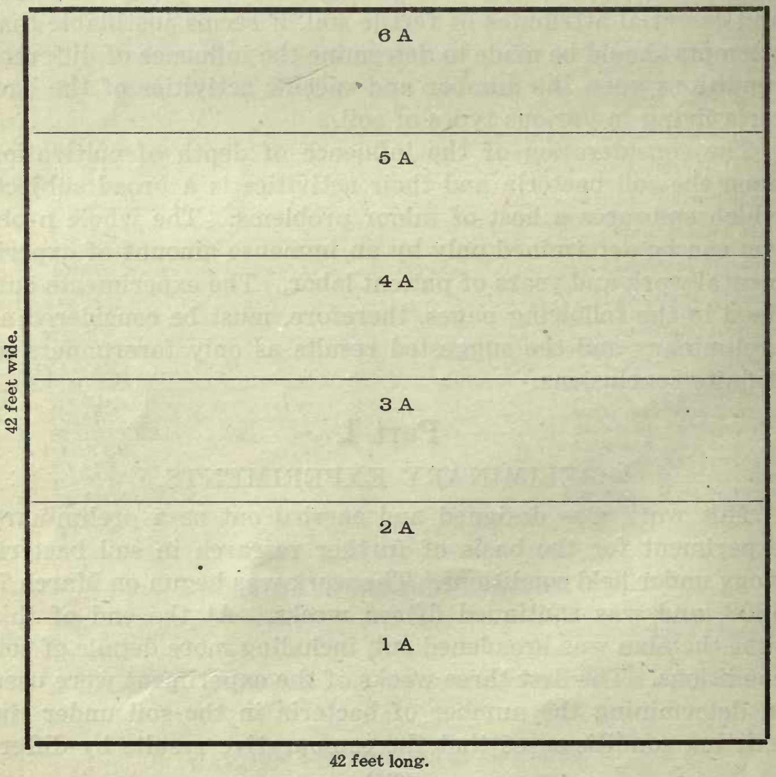
Part I.

PRELIMINARY EXPERIMENTS.

This work was designed and carried out as a preliminary experiment for the basis of further research in soil bacteriology under field conditions. The work was begun on March 7, 1908, and was continued fifteen weeks. At the end of this time the plan was broadened out, including more details of soil conditions. The first three weeks of the experiment were used in determining the number of bacteria in the soil under the existing conditions, so that the comparative results by different treatments must be drawn from the last twelve weeks' work.

The study included two types of soil as nearly opposite in character as it was possible to secure. Silt loam and fine sandy loam were selected. The silt loam is situated upon the upland Kansas State Agricultural College farm. This had previously been used for an experimental plot; the year previous it was planted to corn but received no special treatment or dressing. The sandy loam is located on the Kaw river bottom close to the stream; it had previously been used for general farming. The fall before this experiment was commenced it had received a liberal dressing of straw manure. A plot 42 x 42 feet was laid out on each field. The one on silt loam was called B; the one on sandy loam was called A. These plots were subdivided into six smaller plots, and called 1B, 2B, 3B, etc. Those of A were likewise named. The following diagram illustrates the plan of each plot:

PLOT A.



Subplots 1A and 1B remained in the original condition and received no treatment, except to keep the weeds down. This was done by shaving them off at the surface of the ground with a hoe. The remainder of the subplots, from 2 to 6 of both A and B, were stirred to a depth of two inches after every rain, as soon as the soil was dry enough to till. Subplots 2, 3, 4, 5 and 6, of both A and B, were plowed to a depth of two, four, six, eight and ten inches, respectively.

In order to determine the influence of the different depths of cultivation on the number of bacteria, six samples were taken from each subplot every seventh day. These samples were taken every second inch to the depth of twelve inches. The estimates are given as so many million bacteria per cubic centimeter. The high bacterial content obtained in some instances is perhaps due to the methods used in this work. The volumetric method of collection and preparation of samples was used exclusively.

At the same time that samples were taken for bacterial determination, samples were also taken to determine the per cent. of moisture in the surface foot of the soil. Each plot was provided with a thermometer, so that the temperature could be recorded each time the samples were taken. The results are given in the following tables (I to XII) :

TABLE I—PLOT A. Check plot, undisturbed.—Fine sandy loam (U. S. Soil Survey). Number of bacteria given as millions per cubic centimeter.

DATE.	Plot No.	Temp., C.	Per cent. water.	Number of bacteria at different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 19①..	1A	10.0	20.17	9.70	10.92	8.64	8.82	4.74	2.88
" 25....	1A	10.0	20.10	11.16	14.26	13.68	8.00	5.40	2.52
Apr. 2....	1A	10.5	20.10	12.00	15.00	6.60	6.60	6.00	2.40
" 9....	1A	11.0	20.25	15.00	10.80	8.40	6.00	4.20	3.00
" 16....	1A	14.9	20.30	11.40	10.92	16.80	10.80	18.00	5.46
" 23....	1A	17.0	24.50	30.06	12.06	4.44	3.60	1.20	1.20
" 30....	1A	16.6	24.50	16.20	18.00	4.20	3.20	1.20	1.20
May 6....	1A	17.5	24.70	15.00	8.40	8.40	4.20	4.80	4.20
" 13....	1A	19.7	25.00	x	x	x	x	x	x
" 20....	1A	16.6	25.40	4.79	5.38	3.58	4.18	2.38	.59
" 27②..	1A	18.6	27.20	13.72	lost	5.32	2.40	5.32	1.10
Jun. 2....	1A	20.0	27.90	22.00	18.40	6.40	4.60	7.40	3.80
" 9....	1A	20.5	25.20	12.60	7.20	6.00	4.20	1.80	.60
Totals..............................				173.63	131.34	92.46	66.60	62.44	28.95
Averages....................				14.47	11.94	7.71	5.55	5.20	2.41

1. Determinations made on March 19 indicate number of bacteria at beginning of experiment.
2. Samples taken after field had been saturated for several days.

Moisture estimates indicate per cent. average in first foot, one determination being made for all plots.

In all cases "x" indicates a spreading growth on plate cultures which prevented counting of colonies.

TABLE II—PLOT 2A. Stirred to the depth of two inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria at different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	2A	10.0	20.17	13.32	20.88	10.08	10.00	1.98	6.84
Apr. 2....	2A	10.5	20.10	14.40	18.00	18.00	12.60	2.40	2.40
" 9....	2A	11.0	20.25	11.40	12.00	9.36	8.70	7.20	4.80
" 16....	2A	14.9	22.80	10.80	8.46	4.26	4.80	1.20	1.80
" 23....	2A	17.0	24.60	11.40	9.00	29.52	13.20	18.60	4.26
" 30....	2A	16.6	24.50	4.20	6.60	12.00	7.80	5.40	2.40
May 6....	2A	17.5	24.70	16.40	12.40	9.20	9.20	6.80	7.60
" 13....	2A	19.7	25.00	x	x	x	x	x	x
" 20....	2A	16.6	25.40	2.98	2.98	3.58	1.18	1.18	.68
" 27....	2A	18.6	27.20	15.12	13.50	7.72	2.92	1.72	2.32
Jun. 2....	2A	20.0	27.90	11.80	17.20	10.00	1.00	1.60	2.20
" 9....	2A	20.5	25.20	7.20	6.80	5.60	2.80	3.20	1.20
Totals..............................				119.02	127.82	119.26	74.20	51.28	36.50
Averages....................				10.82	11.62	10.84	6.74	4.66	3.31

TABLE III—PLOT 3A. Stirred to depth of four inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria at different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	3A	(See plot 2A)....		34.20	42.80	19.80	17.28	8.28	4.68
Apr. 2....	3A	"	"	9.00	16.20	16.20	14.40	6.60	3.00
" 9....	3A	"	"	15.00	28.20	①61.00	10.80	6.00	5.40
" 16....	3A	"	"	4.80	4.26	9.00	3.66	1.92	1.92
" 23....	3A	"	"	20.40	22.32	11.46	9.00	1.62	5.52
" 30....	3A	"	"	9.00	2.60	8.40	2.40	2.40	.60
May 6....	3A	"	"	34.80	35.20	11.20	2.52	2.80	6.40
" 13....	3A	"	"	x	x	x	x	x	x
" 20....	3A	"	"	6.58	5.98	6.00	8.98	4.78	0.58
" 27....	3A	"	"	16.72	13.72	10.10	10.12	4.10	1.10
Jun. 2....	3A	"	"	14.20	22.60	9.40	5.80	4.00	3.80
" 9....	3A	"	"	4.80	4.80	6.00	4.00	1.20	.40
Totals..............................				169.50	198.68	168.56	88.96	43.70	33.40
Averages....................				15.40	18.06	15.32	8.08	3.97	3.03

1. Bunch of manure is responsible for large number of bacteria.

TABLE IV—PLOT 4A. Stirred to depth of six inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria at different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	4A	(See plot 2A.)		11.04	11.28	8.16	8.16	5.28	4.00
Apr. 2....	4A	"	"	12.00	18.60	27.40	6.60	4.20	3.40
" 9....	4A	"	"	9.00	12.60	14.40	16.80	9.60	5.40
" 16....	4A	"	"	8.40	19.32	7.32	6.60	3.72	1.92
" 23....	4A	"	"	10.32	42.60	39.66	16.32	7.80	3.00
" 30....	4A	"	"	3.00	6.00	6.00	2.40	1.80	.60
May 6....	4A	"	"	14.80	15.60	13.60	2.20	1.60	2.80
" 13....	4A	"	"	x	x	x	x	x	x
" 20....	4A	"	"	5.98	7.78	①20.98	2.38	3.58	.98
" 27....	4A	"	"	16.72	15.52	10.10	6.50	2.32	5.32
Jun. 2....	4A	"	"	11.60	15.60	8.00	5.20	.60	2.80
" 9....	4A	"	"	3.60	7.60	6.40	4.80	.80	.05
Totals..............................				106.46	172.50	162.02	77.96	41.30	30.27
Averages				9.67	15.68	14.73	7.08	3.75	2.75

1. Bunch of manure is responsible for large number of bacteria.

TABLE V—PLOT 5A. Stirred to a depth of eight inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria at certain depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25	5A	(See plot 2A)		7.92	9.12	6.72	6.48	4.56	3.84
Apr. 2	5A	“	“	12.40	26.40	①42.00	12.00	7.00	6.60
“ 9	5A	“	“	8.40	8.46	8.40	12.00	6.00	6.00
“ 16	5A	“	“	3.72	12.06	9.72	10.32	3.00	3.60
“ 23	5A	“	“	30.00	16.32	12.84	8.58	7.26	9.06
“ 30	5A	“	“	4.20	2.40	6.00	12.60	6.12	.62
May 6	5A	“	“	8.88	14.00	15.60	30.80	6.80	6.00
“ 13	5A	“	“	x	x	11.98	x	x	x
“ 20	5A	“	“	19.18	8.40	x	13.78	2.98	3.58
“ 27	5A	“	“	6.00	9.00	17.32	7.70	lost	7.70
Jun. 2	5A	“	“	11.20	4.60	11.80	19.20	2.00	12.00
“ 9	5A	“	“	9.60	6.80	12.60	5.60	.40	1.20
Totals				121.50	117.56	154.98	139.06	46.12	60.20
Averages				11.04	10.68	14.09	12.64	4.61	5.47

1. The large number of bacteria is due to manure.

TABLE VI—PLOT 6A. Stirred to a depth of ten inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria at different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25	6A	(See plot 2A)		9.12	10.80	7.92	8.16	13.20	1.44
Apr. 2	6A	“	“	6.00	7.20	14.40	5.40	4.00	3.60
“ 9	6A	“	“	7.20	10.80	9.60	11.40	11.40	8.40
“ 16	6A	“	“	4.20	10.20	6.12	①........	16.20	5.52
“ 23	6A	“	“	6.72	10.20	10.80	18.75	10.92	7.20
“ 30	6A	“	“	6.00	9.00	3.60	3.00	5.40	6.60
May 6	6A	“	“	①........	6.80	11.20	15.60	5.20	4.80
“ 13	6A	“	“	x	x	x	x	x	x
“ 20	6A	“	“	9.58	10.78	16.18	7.78	12.58	5.98
“ 27	6A	“	“	12.50	lost	16.10	lost	lost	8.32
Jun. 2	6A	“	“	4.00	5.60	4.40	8.80	4.60	1.60
“ 9	6A	“	“	8.00	8.80	11.20	4.40	2.40	5.60
Totals				73.32	90.18	111.52	83.29	85.90	59.06
Averages				7.33	9.01	10.13	9.27	8.59	5.37

1. So many colonies that they could not be counted.

TABLE VII—PLOT B. Check plot, undisturbed.—Preliminary experiment—Marshall silt loam (U. S. Soil Survey). Numbers indicate millions of bacteria per cubic centimeter.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria at different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 19	1B	10.0	21.87	7.26	8.96	11.66	4.21	2.97	2.65
“ 25	1B	9.2	21.87	9.08	13.04	9.36	5.04	2.52	1.62
Apr. 2	1B	10.0	22.60	4.30	4.90	7.30	1.80	4.20	1.20
“ 9	1B	13.0	22.25	9.00	18.60	2.00	2.40	1.20	2.40
“ 16	1B	15.0	23.80	7.20	12.00	16.20	8.40	2.40	.96
“ 23	1B	14.9	24.60	10.20	4.92	5.40	1.20	3.06	1.30
“ 30	1B	14.0	25.50	12.24	15.84	4.92	3.60	3.60	1.80
May 6	1B	12.4	25.70	9.61	9.60	8.52	9.12	6.60	2.40
“ 13	1B	15.6	25.90	x	x	x	x	x	x
“ 20	1B	19.4	25.40	7.80	8.41	4.20	x	.30	.09
“ 27	1B	19.0	28.20	10.00	7.60	1.60	1.10	.30	.16
Jun. 2	1B	18.0	28.90	6.40	8.80	1.00	.60	.30	.50
“ 9	1B	20.0	26.80	25.20	11.40	9.60	10.20	3.60	2.40
Totals				118.29	124.07	81.76	47.67	31.05	17.48
Averages				9.85	10.34	6.81	4.33	2.58	1.45

TABLE VIII—PLOT 2B. Stirred to depth of two inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria at different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	2B	9.2	21.87	9.02	6.72	4.32	2.88	2.88	3.24
Apr. 2....	2B	10.0	22.60	6.10	5.40	3.60	2.40	1.80	1.20
" 9....	2B	13.0	22.25	18.60	7.20	7.20	4.80	2.40	.60
" 16....	2B	15.0	23.80	10.80	10.20	15.00	12.00	12.00	7.20
" 23....	2B	14.9	24.60	8.64	7.80	1.20	3.06	.60	.50
" 30....	2B	14.0	25.50	6.90	52.20	6.20	3.18	.66	1.86
May 6....	2B	12.4	25.70	12.60	9.00	10.20	5.40	9.18	6.12
" 13....	2B	15.6	25.90	x	x	x	x	x	x
" 20....	2B	19.4	25.40	8.40	2.41	1.20	.66	.12	.05
" 27....	2B	19.0	28.20	4.00	4.70	.70	.70	1.20	.40
Jun. 2....	2B	18.0	28.90	13.60	14.80	1.00	1.00	.50	.80
" 9....	2B	20.0	26.80	15.60	11.40	6.60	4.20	3.60	1.80
Totals..................................				114.26	131.83	57.22	40.28	34.94	23.77
Averages....................				10.38	11.99	5.20	3.66	3.17	2.16

TABLE IX—PLOT 3B. Stirred to depth of four inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria in different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	3B	9.2	21.89	8.64	6.96	2.53	2.18	1.88	3.24
Apr. 2....	3B	10.0	22.60	8.50	12.60	8.40	1.80	1.30	6.60
" 9....	3B	13.0	22.25	7.20	12.60	5.40	4.60	4.60	2.90
" 16....	3B	15.0	23.80	9.72	10.32	21.12	20.40	20.40	9.60
" 23....	3B	14.9	24.60	10.20	6.00	1.80	1.80	1.80	1.86
" 30....	3B	14.0	25.50	10.20	12.78	13.26	3.12	3.12	1.20
May 6....	3B	12.4	25.70	9.18	9.72	6.00	6.60	6.60	9.00
" 13....	3B	15.6	25.90	x	x	x	x	x	x
" 20....	3B	19.4	25.40	4.80	6.60	1.80	.27	.27	.21
" 27....	3B	19.0	28.20	10.70	8.90	10.70	1.20	1.20	.10
Jun. 2....	3B	18.0	28.90	24.40	11.60	2.20	.20	.20	.10
" 9....	3B	20.0	26.80	17.40	16.80	2.40	9.00	9.00	6.60
Totals..................................				121.94	114.88	75.61	51.17	50.37	35.41
Averages....................				11.08	10.44	6.87	4.65	4.58	3.21

TABLE X—PLOT 4B. Stirred to a depth of six inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria in certain depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	4B	9.2	21.87	4.36	4.32	12.96	6.04	3.60	3.60
Apr. 2....	4B	10.0	22.60	5.40	7.80	9.00	1.80	1.80	1.20
" 9....	4B	13.0	22.25	12.00	17.40	19.20	4.20	4.80	1.20
" 16....	4B	15.0	23.80	8.64	15.12	13.60	12.06	9.06	①16.26
" 23....	4B	14.9	24.60	6.12	3.60	4.32	.50	.48	1.14
" 30....	4B	14.0	25.50	9.00	5.10	4.32	5.43	3.00	.59
May 7....	4B	12.4	25.70	6.72	4.80	8.90	8.60	6.78	4.32
" 14....	4B	15.6	25.90	x	x	x	x	x	x
" 21....	4B	19.4	25.40	14.40	8.40	3.00	.44	.43	.39
" 28....	4B	19.0	28.20	10.20	6.60	3.50	3.60	.16	.36
Jun. 3....	4B	18.0	28.90	16.80	15.90	17.20	1.60	.40	.20
" 10....	4B	20.0	26.80	17.40	9.00	9.60	5.40	3.00	6.60
Totals..................................				108.04	98.04	106.60	49.67	33.51	35.86
Averages....................				9.82	8.91	9.69	4.51	3.04	3.26

1. No adequate reason can be given for the exceptionally high number.

TABLE XI—PLOT 5B. Stirred to depth of 8 inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria in different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	5B	9.2	21.87	8.82	8.20	8.64	8.52	8.28	2.52
Apr. 2....	5B	10.0	22.60	6.00	7.20	7.40	3.00	2.40	1.20
" 9....	5B	13.0	22.25	18.00	19.80	9.00	4.20	3.60	.60
" 16....	5B	15.0	23.80	7.26	13.32	13.20	4.26	3.60	7.80
" 23....	5B	14.9	24.60	7.20	4.20	4.80	1.80	8.50	4.20
" 30....	5B	14.0	25.50	16.32	18.60	14.84	9.20	.80	1.20
May 6....	5B	12.4	25.70	10.32	9 00	11.40	10.30	7.20	6.60
" 14....	5B	15.6	25.90	x	x	x	x	x	x
" 21....	5B	19.4	25.40	x	x	6.00	9.60	.16	.23
" 28....	5B	19.0	28.20	14.30	8.30	7.70	2.30	1.70	1.10
Jun. 3....	5B	18.0	28.90	4.00	19.60	10.60	2.00	.10	.90
" 10....	5B	20.0	26.80	9.00	27.00	12.60	4.80	4.20	1.20
Totals..........................				101.22	136.22	106.18	59.98	40.54	27.55
Averages....................				10.12	13.52	9.65	5.45	3.68	2.50

TABLE XII—PLOT 6B. Stirred to a depth of ten inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria in different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	6B	9.2	21.87	2.88	3.60	19.64	2.88	2.52	1.42
Apr. 2....	6B	10.0	22.60	2.40	8.40	3.20	3.60	14.40	2.40
" 9....	6B	13.0	22.25	7.20	6.60	7.80	7.90	7.20	6.60
" 16....	6B	15.0	23.80	10.20	24.60	27.00	12.06	12.00	12.00
" 23....	6B	14.9	24.60	9.18	13.20	6.06	1.00	.30	.20
" 30....	6B	14.0	25.50	5.52	18.88	16.64	6.00	5.60	.80
May 7....	6B	12.4	25.70	3.18	10.80	12.00	7.80	8.40	6.60
" 14....	6B	15.6	25.90	x	x	x	x	x	x
" 21....	6B	19.4	25.40	3.00	3.00	4.20	3.00	4.80	3.60
" 28....	6B	19.0	28.20	6.50	9.00	9.50	3.50	1.10	1.70
Jun. 3....	6B	18.0	28.90	1.00	15.40	16.00	9.40	.80	.60
" 10....	6B	20.0	26.80	6.60	11.40	15.00	15.00	7.20	5.40
Totals..........................				57.66	124.88	137.04	72.14	64.32	41.32
Averages....................				5.24	11 35	12.45	6.56	5.85	3.75

The great variation in the results is at once apparent. This fluctuation, however, generally occurs in quantitative soil bacteriological work. Samples taken 100 feet apart may often show a variation of 20 to 40 per cent., while those taken from the same depth, only a few feet apart, may vary from 10 to 20 per cent. Commencing at the surface, bacteria increase in number up to the fifth or sixth inch, depending upon the depth of plowing, then rapidly decrease, and disappear at a depth of about seven feet below the surface foot.

Some of the exceptional irregularities in the table can be explained. For instance, on April 23, plot 2A showed twenty-nine million bacteria per cubic centimeter at six inches, thirteen million at eight inches, and eighteen million at ten inches in depth. These high numbers are due to a portion of manure which had been plowed under the year previous and had not entirely decayed. The piece of manure, to all appearances, had been pressed into some rodent's runway by the horses' hoofs. The average depth of the previous plowing was approximately four inches. The same thing occurred in the samples taken on the same day on plot 4A. The number of bacteria reached forty-two million per cubic centimeter in the fourth inch and thirty-nine million per cubic centimeter in the sixth inch. Again, on April 9, plot 3A showed sixty-one million per cubic centimeter in the sixth. This was also due to manure. Another factor which probably induced these large numbers was the increased temperature, followed by a warm two-inch rain which fell about twenty-four hours before the samples were taken. This view is strengthened by glancing through the twelve tables and comparing estimates for April 23. The sandy soils, which allowed a rapid percolation of water, showed a marked increase in number of bacteria, even in the tenth and twelfth inches, but the more tenacious silt soils showed a decrease in the number of bacteria. The temperature of the silt during the preceding week was 15 degrees C., while on April 23 it had fallen to 14.9 degrees C. The temperature of the sand was 14.9 degrees on April 16, while on April 23 it had risen to 17 degrees C. Plot 4B shows an unaccountable high number in the twelfth inch on the 16th of April.

The tables show that the number of bacteria increased and diminished with more or less regularity. It was also observed on the plate cultures that one species of bacteria would predominate, and at times almost entirely exclude other species. For instance, on April 9 the sixty-one million count consisted almost entirely of minute oval colonies, all of which were apparently of one species.

On May 13 both plots A and B gave results that were exceptional. On the plate cultures there were innumerable tiny colonies so closely set that they could not be accurately estimated. However, estimates placed them at one hundred million per cubic centimeter. One week later, May 20, all the plots showed a marked decrease in the number of organisms. This was perhaps due to the excessive moisture, the ground having been completely saturated for several days; nevertheless, the growth on the agar plates was apparently all of one species.

The influence of moisture is perhaps best shown by the results obtained between May 20 and June 2. During this time the soil was more or less saturated. It will be noticed that the number of bacteria diminished quite markedly during this period, and rose again on June 2 nearly to its former height, followed by a decrease on June 9. This was after the per cent. of moisture in the sandy soil had fallen from 27.9 to 25.2 per cent., and from 28.9 to 26.8 in the silt.

A better idea of the influence of deep plowing can be obtained by arranging the averages of tables from 1 to 6 in one table and the averages from tables 7 to 12 in another and comparing the results:

TABLE XIII. Sandy loam.

Depth of sample.	Average number bacteria.					
	1A. Undisturbed.	2A. Stirred 2 in.	3A. Stirred 4 in.	4A. Stirred 6 in.	5A. Stirred 8 in.	6A. Stirred 10 in.
2 inches	14.47	10.82	15.40	9.67	11.04	7.33
4 "	11.94	11.62	18.06	15.68	10.68	9.01
6 "	7.71	10.84	15.32	14.73	14.09	10.13
8 "	5.55	6.74	8.08	7.08	12.64	9.27
10 "	5.20	4.66	3.97	3.75	4.19	8.59
12 "	2.41	3.31	3.03	2.75	5.47	5.37
Sum of averages	47.28	47.99	63.86	53.66	58.11	49.70

TABLE XIV. Silt loam.

Depth of sample.	Average number bacteria.					
	1B. Undisturbed.	2B. Stirred 2 in.	3B. Stirred 4 in.	4B. Stirred 6 in.	5B. Stirred 8 in.	6B. Stirred 10 in.
2 inches	9.85	10.38	11.08	9.82	10.12	5.24
4 "	10.34	11.99	10.44	8.91	13.52	11.35
6 "	6.81	5.20	6.87	9.69	9.65	12.45
8 "	4.33	3.66	4.65	4.51	5.45	6.56
10 "	2.58	3.17	4.58	3.04	3.68	5.85
12 "	1.45	2.16	3.21	3.26	2.50	3.75
Sum of averages	35.36	36.56	40.83	39.23	44.92	45.20

The average in tables XIII and XIV does not give the total number of bacteria in a surface foot of soil, but shows the ratio of the number of bacteria. For instance, in table XIII (sandy soil) the sum of the averages for the unstirred check plot was 47.28 million. The bacterial contents of 3A, 4A and

5A, stirred four, six and eight inches deep, were 63.86, 53.66 and 58.11 million, respectively. In the plot which was stirred ten inches deep the number was slightly less than in the plot which was stirred four inches deep. The plots which were plowed to a depth of two, four, six, eight and ten inches showed an increase in the number of bacteria of 0.71, 16.58, 6.38, 10.83 and 2.42 millions per cubic centimeter, respectively.

Upon examination of table XIV it will be found that in the silt soil the increase in the number of bacteria, due to deeper plowing, is not so rapid as in the sandy soil, but much more uniform. Commencing with plot 2B, the number of bacteria shows a gradual increase from 1.20 million in the two-inch plowing to 9.84 million in the ten-inch plowing.

The percentage of increase of bacterial content is shown in table XV.

TABLE XV.

Subplot number.	Sum of the averages.	Depth of cultivation.	Percentage of increase.
1A sand	47.28	Check, undisturbed	100.00
1B silt	35.36	" "	100.00
2A sand	47.99	Plowed two inches deep	101.50
2B silt	36.56	" " " "	103.39
3A sand	63.86	" four " "	135.06
3B silt	40.83	" " " "	115.46
4A sand	53.66	" six " "	113.53
4B silt	39.23	" " " "	110.94
5A sand	58.11	" eight " "	122.90
5B silt	44.92	" " " "	124.20
6A sand	49.70	" ten " "	105.11
6B silt	45.20	" " " "	126.89

From the results in table XV it appears that extra deep cultivation tends to greater increase in numbers of bacteria upon the tenacious silt soil than upon the more porous sandy soils. This effect in favor of the silt soil is perhaps due largely to the increased aeration. At the same time it is well to observe that the silt soil had previously been plowed about six inches deep, while the sandy soil had been plowed on an average of four inches deep. Hence, in stirring the silt soil ten inches deep, four inches of new soil were exposed, while with the sandy soils that were stirred the same depth six inches of new soil were brought into action. This deep plowing would tend to place the surface soil, high in humus content, at a depth that is less favorable for highest bacterial development and at the same time place the previously unstirred soil, of low humus content, in the most favorable growing area.

If, however, the field were stirred to a depth of ten inches for several years, so as to incorporate humus into the surface ten inches of soil, it is reasonable to suppose that extra deep plowing might be more favorable for the development of bacteria in the sandy soil than it appears to be from the above table. At the same time, however, several years of deep plowing would also be more beneficial to bacterial development in the heavier soils.

These preliminary experiments show that when plowed land is compared with unplowed land it is found that:

Silt—	
Plowed 4 inches deep increases the number of bacteria......	15.46%
Plowed 6 inches deep increases the number of bacteria......	10.94
Plowed 8 inches deep increases the number of bacteria......	24.20
Plowed 10 inches deep increases the number of bacteria......	26.89
Sand—	
Plowed 4 inches deep increases the number of bacteria......	35.06%
Plowed 6 inches deep increases the number of bacteria......	13.53
Plowed 8 inches deep increases the number of bacteria......	22.90
Plowed 10 inches deep increases the number of bacteria......	5.11

Part II.

CONTINUATION OF THE EXPERIMENTS.

On June 20, 1908, the experiments were continued, and determinations were made according to the following plan:

PLOT A (42 x 42 feet).

Subplot A1. Six samples to be taken every 14 days, volumetric method. (Undisturbed.) (See note.)	Subplot A1. Six samples to be taken every 14 days, volumetric method. (Unstirred.)
A2. Six samples to be taken every 14 days, volumetric method. (Stirred 2 inches.)	A2. Six samples to be taken every 14 days, volumetric method. (Stirred 2 inches on March 18 and June 20.)
A3. Six samples to be taken every 14 days, volumetric method. (Stirred 4 inches on March 18.)	A3. Six samples to be taken every 14 days, volumetric method. (Stirred 4 inches on March 18 and June 20.)
A4. Six samples to be taken every 14 days, volumetric method. (Stirred 6 inches on March 18.)	A4. Six samples to be taken every 14 days, volumetric method. (Stirred 6 inches on March 18 and June 20.)
A5. Six samples to be taken every 14 days, volumetric method. (Stirred 8 inches on March 18.)	A5. Six samples to be taken every 14 days, volumetric method. (Stirred 8 inches on March 18 and June 20.)
A6. Six samples to be taken every 14 days, volumetric method. (Stirred 10 inches on March 18.)	A6. Six samples to be taken every 14 days, volumetric method. (Stirred 10 inches on March 18 and June 20.)

NOTE.—Eighteen samples taken by gravimetric method and eighteen samples by volumetric method at the same time and place.

One-half of each subplot in A and also one-half of each subplot in B* were replowed to the same depth as on March 18, in order to see if further stirring of the soil would increase the number and activities of the soil organisms.

The purpose of taking gravimetric samples was to obtain results which would afford a basis for a comparison of the two methods of soil sampling. The gravimetric or weighed samples were secured from the same plots and at the same depth and place as the volumetric or measured samples. There were two sets of gravimetric samples taken, in order to determine whether drying materially decreased the number of bacteria per gram. One set of gravimetric samples with duplicates was taken immediately to the right of the volumetric samples; the other set with duplicates was taken immediately to the left of the volumetric samples, so as to obtain under the same conditions, as nearly as possible, the same type of soil.

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* Plot B, 42 x 42 feet, duplicate of Plot A.

The method employed for taking and caring for individual samples will be discussed under "Quantitative Bacteriological Analysis." After taking the samples to the laboratory, one gravimetric set with duplicates was immediately subjected to culture tests; the other set with duplicates was placed between sheets of sterile filter-paper until air dry. Twenty-four hours was found sufficient for that purpose. They were then treated as were the other samples.

BACTERIAL ACTIVITIES AND INFLUENCING CONDITIONS.

In order to find the influence of aeration upon the biochemic characters of bacteria, determinations were made of the production of ammonia, reduction of nitrates to nitrites, and the production of gas in one-per-cent. solutions of glucose, lactose and saccharose bouillon.

Ammonia Production.—The relative amounts of ammonia in the different samples of soil were determined in the following way: One cubic centimeter of soil was completely suspended in nineteen cubic centimeters of sterile, ammonia-free, distilled water. Two cubic centimeters of this soil suspension were transferred to fifty cubic centimeters of nutrient agar, having a reaction of 1.5 acid to phenolpthalein. The agar was distributed in Erlenmeyer flasks of 250 cc. capacity. The flasks were then closed and allowed to stand for five days. At the end of that time ten cubic centimeters of sterile, nitrogen-free water were introduced and allowed to stand for ten minutes. It was then drawn off and tested for ammonia with Nessler's solution. The color reaction was compared with standard solutions and the results recorded as so many parts of ammonia per million. These standard solutions were prepared by placing fractional percentages of ammonium chloride in nitrogen-free water.

Gas Production.—The production of gas was determined in the usual way by using the common sugar bouillon media in fermentation tubes, each of which were inoculated with two cubic centimeters of soil suspension.

Reduction of Nitrates to Nitrites.—The denitrifying properties, or reduction of nitrates to nitrites, were determined by inoculating with 2 cubic centimeters of soil suspension, 10 cubic centimeters of Witte's peptone medium, which contained 0.2 gram of potassium nitrate per 1000 cubic centimeters. The tubes were allowed to stand for five days and then tested for nitrites by the addition of sulfanilic acid and naphthylamine chlorid. The results were compared with a standard and recorded as so many parts of nitrites per million.

Temperature.—In the preliminary work the temperature was recorded for the surface foot, but commencing with July 6, the temperature was recorded for each successive second inch up to one foot, or for each soil sample taken.

Acidity of Soil.—At the beginning of the experiment the soil showed acid to litmus at the end of thirty minutes, while at the end of the experiment it showed acid to litmus at the end of ten minutes.

Field Notes.—The condition of the soil surface, the time which had elapsed since the last rain, the amount of precipitation, and other factors such as masses of undecomposed organic matter, plowed soil, unstirred subsoil and burrows or heavy roots were recorded when samples were taken.

Mechanical Analyses.—A mechanical analysis was made of each of the two plots of soil under observation. The results of these analyses were as follows:

SILT SOIL, PLOT B.

Humus	3.15	per cent.
Volatiles	4.86	"
Fine gravel	.00	"
Coarse sand	.20	"
Medium sand	.26	"
Fine sand	.46	"
Very fine sand	24.16	"
Silt	38.91	"
Clay	28.00	"
Total	100.00	per cent.

SANDY SOIL, PLOT A.

Humus	3.25	per cent.
Volatiles	5.86	"
Fine gravel	.00	"
Coarse sand	.28	"
Medium sand	.38	"
Fine sand	3.72	"
Very fine sand	64.80	"
Silt	17.18	"
Clay	4.53	"
Total	100.00	per cent.

Number and Manner of Taking Samples.—From each half of the subplots which were plowed on March 18, and from each half of the subplots which were plowed on March 18 then replowed on June 20, six samples for bacterial determination were taken every fourteenth day. Six samples with duplicates for volumetric bacterial determination were taken from check plot A1 and the same number from check plot B1.

QUANTITATIVE BACTERIOLOGICAL ANALYSIS.

One of the difficult problems in soil bacteriological technique is that relating to the proper method of taking and measuring samples for quantitative determination. It is the general custom of bacteriologists to compare the number of bacteria per gram of dry soil. This is sometimes called the gravimetric or gram method.

In the present experimental work the volumetric method has been used. One cubic centimeter of soil was placed in a sterile test-tube to which was added 19 cc. of sterile distilled water. This was shaken for five minutes, and from each tube, by means of a sterile platinum loop, which was constructed and graduated to hold one cubic millimeter of water, approximately one cubic millimeter of the soil suspension was transferred into 10 cc. of sterile liquefied agar. The inoculated medium was then poured into a sterile Petri dish. This method is undoubtedly inaccurate, as it is difficult to measure such substances as soil in terms of cubic centimeters. However, for the purpose of securing comparative results, as in the present work, either method may be used. In other words, the comparative number of bacteria in soil which has been plowed two, four, six, eight, ten and twelve inches deep may be found by either the volumetric or gravimetric method and expressed as so many bacteria per cubic centimeter or per gram. The final results would appear to be correct so long as one or the other method of collecting samples is followed with uniformity throughout the work.

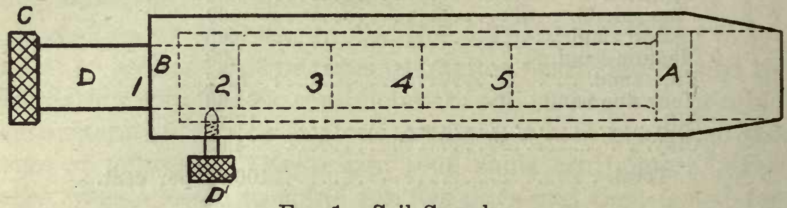


FIG. 1. Soil Sampler.

OBTAINING SAMPLES, AND BACTERIOLOGICAL TECHNIQUE.

The field outfit used in the work consisted of a small steel soil sampler, a spade, a measure, a sample case and a gasoline blow-torch. The soil sampler (fig. 1) is made of steel and consists of a steel tube seven centimeters long with an inside diameter of three-eighths inch and an outside diameter of seven-sixteenths inch. The plunger (D), with a plunger-rod one-eighth inch in diameter, is connected with the cylinder through a one-eighth inch hole (B), and is clamped and held at the desired place by the set-screw (*D*). The plunger-head (A) is just a working fit inside the cylinder. The plunger-rod (D) is graduated so that the plunger-head allows 1, 2, 3 or 4 cc. of soil to be taken, as desired.

The Sample Case.—The sample case (figs. 2 and 3) is 24 inches long, 18 inches high, and 12 inches wide. A lid, to which is attached the handle, covers the entire top. This is raised and the two catches at either end are released, which allows the case to open. On each side of the case, running the entire length, are three perforated shelves for holding test-tubes. The top shelf is two inches wide and holds 20 test-tubes. The second shelf is four inches wide and holds 20 test-tubes, while the lower shelf is six inches wide and holds the same number of tubes. The entire case holds 120 test-tubes, and when full weighs 7.45 kilograms.

The reason for having the shelves of different widths can be seen in the cut, as it allows the handling of one row of test-tubes without disturbing the others. The test-tube perforations are numbered to correspond with the depth of the sample and number of the plot, so that when a sample is taken the corresponding test-tube can be filled and replaced, thus

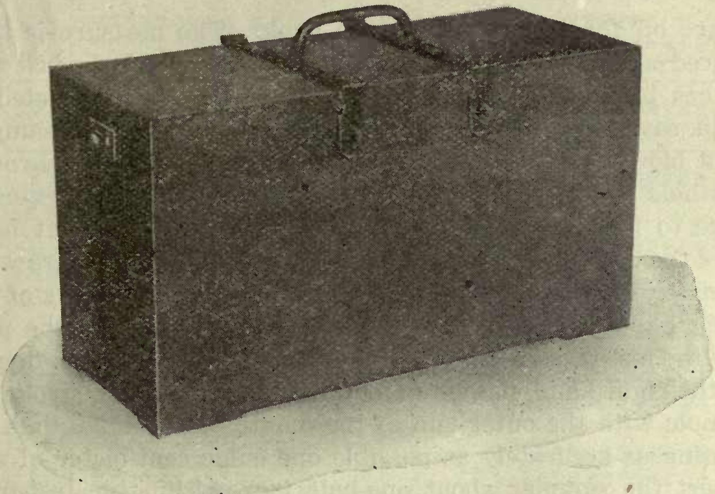


FIG. 2. Sample case, closed.

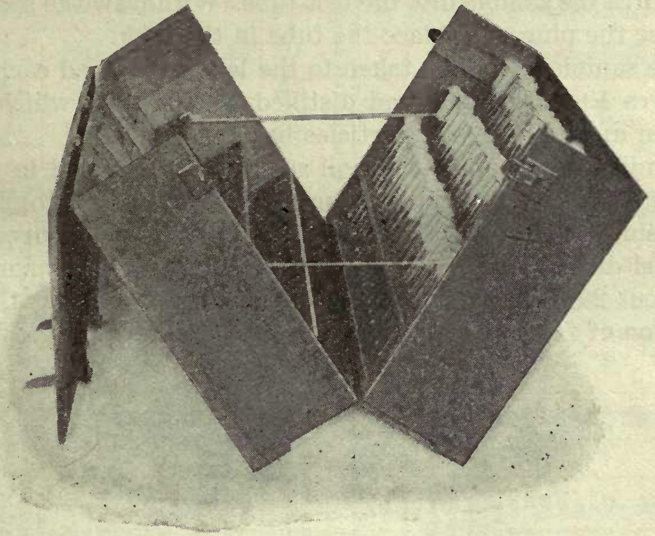


FIG. 3. Sample case, opened.

doing away with needless labeling of tubes. The case can be transferred to the laboratory and the cultures made.

The measure consists of a lath two feet long into which has been bored one-half inch holes every two inches, commencing with the second inch.

Taking the Samples.—To take the samples, dig a hole about a foot square, to the required depth. With a sterile spatula shave off foreign dirt from one bank. The measure is then placed against this bank and held so that a hole is just two inches below the surface. The sampler is then adjusted to take, say, 1 cc. (see fig. 1). After sterilizing the steel sampler in a blow-torch, with the right hand pass the point through the hole in the measure and force it into the soil, turning it once to free the outside from the soil. With the left hand take the corresponding test-tube from the case. Withdraw the sampler, holding it between the first and second fingers of the right hand, loosen the set-screw with the left, draw the plug (of the test-tube) with the back of the third and fourth fingers of the right hand, flame the mouth of the tube, then stroke the sample with the outer rim of the mouth of the tube, thus obtaining as accurately as possible one cubic centimeter of soil. Insert the sampler about one-half inch within the test-tube, then place the thumb of the right hand upon the plunger-head and force the sample into the test-tube. Withdraw the sampler, replace the plug, and place the tube in the rack.

The samples are then taken to the laboratory and each tube receives 19 cc. of sterilized distilled water, after which it is shaken until all the soil particles have separated.

A millimeter loop of this soil suspension is placed in 10 cc. of liquefied nutrient agar having a reaction of +1.5 to phenolpthalein, and the inoculated medium shaken and poured into a Petri dish. The plate cultures were kept at a temperature of about 23 degrees C. The colonies were counted at the expiration of from twenty to twenty-four hours.

TABLE I. Comparative number of bacteria per gram and per cubic centimeter. Plot A, wet.

Depth, inches.	7—6	No. of bacteria.		7—20	No. of bacteria.		8—3	No. of bacteria.		8—17	No. of bacteria.		8—31	No. of bacteria.	
	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.
2	1.248	10.20	8.17	1.25	11.20	8.96	1.25	17.60	14.00	1.30	8.40	6.58	1.21	3.60	2.97
2D*	1.25	15.00	12.00	1.16	9.60	8.27	1.25	8.00	6.40	1.29	25.20	19.45	1.22	2.60	2.14
4	1.236	22.80	18.40	1.19	16.80	14.11	1.23	7.20	5.84	1.18	8.40	7.11	1.13	6.60	5.93
4D	1.30	45.00	34.60	1.20	12.00	10.00	1.20	6.40	5.33	1.17	5.40	4.61	1.20	6.00	5.00
6	1.29	11.40	8.83	1.30	5.60	4.30	1.24	6.40	5.16	1.17	10.80	9.23	1.24	6.00	4.83
6D	1.40	23.00	11.64	1.28	4.80	3.70	1.19	9.60	8.06	1.20	7.20	6.00	1.24	6.60	5.32
8	1.31	8.40	6.41	1.10	4.80	4.30	1.80	7.20	5.53	1.19	3.60	3.02	1.26	6.00	4.75
8D	1.23	13.80	11.21	1.09	5.60	5.10	1.28	3.60	2.81	1.20	4.80	4.00	1.21	4.20	3.47
10	1.20	6.00	5.00	1.24	3.60	2.00	1.19	4.80	4.03	1.13	.20	.153	1.19	1.80	1.51
10D	1.19	5.40	4.53	1.30	2.40	1.84	1.24	2.00	1.61	1.24	6.60	5.32	1.20	lost	lost
12	1.30	6.00	4.65	1.23	3.20	2.60	1.30	2.40	1.80	1.20	1.00	.833	1.23	1.20	.97
12D	1.26	6.00	4.76	1.20	4.00	3.33	1.30	2.10	1.61	1.21	.34	2.80	1.22	lost	lost
Totals	....	173.00	130.20	....	83.60	68.51	....	77.30	62.18	....	81.94	66.586	....	44.60	36.89

* D indicates check or duplicate samples.

TABLE II. Number of bacteria per gram. Plot A, dry.

Depth, inches.	7—6	No. of bacteria.		7—20	No. of bacteria.		8—3	No. of bacteria.		8—17	No. of bacteria.		8—31	No. of bacteria.	
	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.
2	1.04	18.00	17.30	0.98	9.60	8.79	1.004	no	result	1.043	13.80	13.20	1.036	5.00	4.80
2D	1.065	34.80	32.60	1.015	5.60	5.40	1.121	20.40	18.20	1.07	10.20	9.53	1.05	2.40	2.08
4	1.112	15.60	13.10	1.05	7.20	6.80	1.085	8.80	8.10	1.06	8.40	7.92	1.06	6.00	5.67
4D	1.062	32.40	30.50	1.04	4.80	4.40	1.075	18.00	16.00	1.05	15.00	14.30	1.06	4.80	4.52
6	1.103	16.80	15.20	1.045	4.80	4.40	1.05	11.20	10.66	1.039	7.20	6.80	1.043	7.20	6.90
6D	1.05	15.00	14.28	1.07	8.00	7.47	1.08	26.40	24.44	1.071	9.60	8.90	1.021	7.20	7.00
8	1.14	7.20	6.30	1.02	3.20	3.03	1.028	9.60	8.60	1.04	3.60	3.46	1.06	3.80	3.58
8D	1.075	13.80	12.80	1.07	5.60	5.23	1.099	14.40	13.10	1.03	4.80	4.66	1.04	2.40	2.30
10	1.07	7.10	6.72	.99	.80	.76	1.031	7.20	6.09	1.067	1.80	1.70	1.04	1.40	1.34
10D	1.049	1.80	1.70	1.05	4.00	3.80	1.025	11.40	11.10	1.09	1.20	1.00	1.07	lost	lost
12	.965	8.40	8.70	1.055	.80	.76	1.04	3.60	3.46	1.05	1.20	1.14	1.09	1.40	1.29
12D	1.078	4.20	3.80	1.047	.80	.76	1.03	10.80	10.44	1.05	2.80	2.66	1.05	lost	lost
Totals	....	175.20	163.00	....	55.20	51.60	....	141.80	130.19	....	79.60	75.27	....	41.60	39.48

TABLE III. Number of bacteria per gram. Plot B, wet.

Depth, inches.	7—9	No. of bacteria.		7—23	No. of bacteria.		8—6	No. of bacteria.		8—20	No. of bacteria.		9—3	No. of bacteria.	
	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.
2	1.135	19.20	16.00	1.14	14.80	14.21	1.21	3.00	2.48	1.11	2.00	1.80	1.12	2.40	2.14
2D	1.129	19.20	16.90	1.142	12.60	11.00	1.20	10.20	8.50	1.11	12.80	11.50	1.16	7.80	6.61
4	1.20	7.20	6.00	1.136	2.40	2.11	1.24	2.40	1.90	1.12	4.80	4.28	1.20	5.40	4.50
4D	1.134	36.80	32.40	1.147	12.60	10.90	1.19	5.40	4.50	1.16	7.80	6.20	1.22	4.80	3.90
6	1.12	3.00	2.67	1.19	2.40	2.01	1.10	4.20	3.818	1.20	.52	.433	1.33	4.80	3.60
6D	1.021	9.60	9.40	1.20	2.40	2.14	1.00	1.80	1.80	1.09	7.20	6.60	1.01	10.80	10.60
8	1.032	.56	.542	1.21	4.20	3.47	1.14	1.20	1.05	1.10	.10	.909	1.19	4.80	4.03
8D	1.23	3.20	2.60	1.18	1.80	1.52	1.20	3.00	2.50	1.00	4.40	4.40	1.07	7.20	6.72
10	1.228	2.40	1.54	1.20	.20	.166	1.14	.06	.05	1.20	.20	.160	1.11	4.80	4.32
10D	1.129	1.60	1.41	1.24	.82	.65	1.16	.16	.13	1.14	4.40	3.80	1.13	7.80	6.90
12	1.134	.02	.0175	1.19	.10	.084	1.20	.04	.033	1.16	.44	.37	1.12	2.40	2.10
12D	1.232	2.40	1.93	1.13	.16	.141	1.10	.10	.0909	1.15	2.80	2.40	1.21	3.80	3 40
Totals	....	105.18	91.41	....	54.48	48.401	....	31.56	26.84	....	46.86	42.85	....	66.80	58.82

TABLE IV. Number of bacteria per gram. Plot B, dry.

Depth, inches.	7—9	No. of bacteria.		7—23	No. of bacteria.		8—6	No. of bacteria.		8—20	No. of bacteria.		9—3	No. of bacteria.	
	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.
2	1.035	9.60	9.20	1.04	6.00	5.76	1.036	10.20	9.80	1.02	6.00	5.88	1.03	4.00	3.78
2D	1.024	30.40	29.50	1.042	9.60	9.20	1.035	1.60	1.035	1.0919	9.00	8.80	1.024	4.20	4.10
4	1.01	6.40	6.30	1.036	6.00	5.70	1.029	3.60	3.40	1.04	5.40	5.19	1.018	4.60	4.50
4D	1.034	8.00	7.70	1.035	6.00	5.70	1.03	11.40	11.06	1.026	4.80	4.60	1.043	4.20	4.00
6	1.02	4.80	4.70	1.029	.38	.36	1.02	4.20	4.10	1.034	3.60	3.40	1.034	3.40	3.20
6D	1.021	4.00	3.90	1.03	2.40	2.33	1.021	3.60	3.50	1.04	6.60	6.34	1.021	9.00	8.80
8	1.032	8.00	7.90	1.03	.26	.25	1.019	1.20	1.10	1.036	8.40	8.10	1.021	3.00	2.90
8D	1.03	5.60	5.43	1.034	.28	.27	1.021	4.20	4.10	1.03	6.00	5.82	1.04	3.00	2.88
10	1.028	2.40	2.30	1.033	.20	.19	1.034	1.20	1.10	1.028	6.00	5.80	1.06	3.40	3.20
10D	1.029	2.40	2.30	1.027	.36	.35	1.021	.12	.11	1.03	3.40	3.30	1.051	lost	lost
12	1.032	4.80	4.60	1.03	2.40	2.35	1.04	.44	.42	1.024	4.20	4.10	1.04	4.20	4.03
12D	1.034	1.60	1.50	1.045	.28	.26	1.029	.20	.19	1.029	.46	.44	1.051	lost	lost
Totals	....	88.00	85.33	....	34.16	32.72	....	41.96	39.91	....	63.86	61.77	....	43.00	41.39

TABLE V—PLOT A (sandy loam). Plowed March 18. Number of bacteria per cubic centimeter, per cent. of moisture, depth in inches, and temperature.

DATE.	Second inch.			Fourth inch.			Sixth inch.			Eighth inch.			Tenth inch.			Twelfth inch.			Plot.	Treatment.
	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.		
Jul. 6......	22.0	11.4	20.0	19.6	11.4	21.2	18.9	9.0	22.4	18.1	10.80	23.0	18.0	2.40	23.0	18.0	4.20	24.0	A1	Undisturbed.
" 20......	20.5	8.4	24.8	21.0	12.0	24.3	20.9	9.6	26.0	20.8	14.40	28.3	20.4	6.00	25.8	19.9	3.60	28.1		
Aug. 3......	25.6	8.4	21.0	24.3	14.4	20.0	22.7	7.2	21.0	22.7	3.00	21.0	22.5	.16	21.0	22.4	.14	22.0		
" 17......	26.3	9.0	20.0	26.2	15.6	23.0	25.8	11.4	24.0	24.7	10.20	23.0	24.3	2.40	24.0	24.2	1.80	25.0		
" 31......	26.2	6.6	24.0	25.2	5.4	20.0	25.3	5.4	21.0	25.6	8.00	21.0	25.7	2.40	24.0	25.7	1.80	23.0		
Jul. 6......	22.0	14.4	21.5	19.6	13.0	22.0	18.0	24.0	25.0	18.1	19.20	25.5	18.0	9.00	25.7	18.0	3.00	26.8	A2	Plowed 2 inches.
" 20......	20.5	21.6	24.8	21.0	21.6	28.0	20.9	18.0	28.0	20.8	18.00	26.0	20.4	4.80	26.1	19.9	1.20	25.8		
Aug. 3......	25.6	14.4	20.0	24.3	4.8	20.0	22.7	13.2	20.0	22.7	6.00	22.0	22.5	.60	22.9	22.4	.26	24.0		
" 17......	26.3	13.2	25.0	26.2	11.4	24.0	25.8	10.2	24.0	24.7	5.40	26.0	24.3	3.40	26.0	24.2	2.40	28.0		
" 31......	26.2	8.4	18.0	25.2	6.6	21.0	25.3	5.4	22.0	25.6	9.60	25.0	25.7	3.00	24.0	25.7	.26	26.0		
Jul. 6......	22.0	15.0	18.9	19.6	x	21.1	18.9	19.2	22.5	18.0	11.40	23 9	18.0	9.60	24.8	18.0	9.00	25.0	A3	Plowed 4 inches.
" 20......	20.5	14.4	26.3	21.0	15.6	26.6	20.9	23.4	25.7	20.8	12.00	26.2	20.4	6.00	25.5	19.9	8.40	25.2		
Aug. 3......	23.6	6.0	18.0	24.3	4.8	22.0	22.7	6.0	23.0	22.7	4.80	24.0	22.5	4.80	24.0	22.0	1.80	25.0		
" 17......	21.3	6.6	25.0	26 2	12.0	25.0	25.8	7.8	24.0	24.7	3.60	25.2	24.3	5.40	25.0	24.2	.88	25.2		
" 31......	21.3	11.4	20.0	25.2	10 8	23.0	25.3	3.6	24.0	25.6	4.80	24.2	25.7	2.40	25.0	25.7	.40	24.9		
Jul. 6......	22.0	12.6	20.0	19.6	27.0	20.0	18.9	21.0	21.1	18.1	20.40	22.3	18.0	28.80	22.8	18.0	5.40	26.6	A4	Plowed 6 inches.
" 20......	20.5	13.2	23.7	21.0	16.8	24.5	20.9	26.4	26.0	20.4	12.00	26.7	20.4	10.80	26.2	19.9	6.60	26.0		
Aug. 3......	25.6	4.8	21.0	24.3	6.0	23.0	22.7	3.6	23.9	22.7	4.80	23.8	22.5	.60	24.0	22.4	.66	24.7		
" 17......	26.3	9.0	23.3	26.2	7.8	24.0	25.8	6.6	22.1	24.5	5.40	25.4	24.3	3.60	26.0	24.2	1.20	26.3		
" 31......	26.2	4.8	18.0	25.2	10.8	22.0	25.3	9.0	22.0	25.6	9.60	22.9	25.7	1.80	23.4	26.7	1.60	25.2		
Jul. 6......	22.0	27.0	20.6	19.6	38.4	20.8	18.9	32.4	21.4	18.1	9.96	21.2	18.0	40.07	23.4	18.0	11.40	24.5	A5	Plowed 8 inches.
" 20......	20.5	27.6	23.3	21.0	30.0	25.8	20.9	16.8	25.2	20.8	22.80	26.4	20.4	12.00	26.7	19.9	8.40	27.0		
Aug. 3......	25.6	8.4	19.0	24.3	4.8	24.0	23.7	7.2	24.1	22.7	15.60	25.5	22.5	3.60	25.4	22.4	9.60	26.1		
" 17......	26.3	4.8	21.0	26.2	6.0	23.0	25.8	8.4	25.0	24.5	12.00	25.4	24.3	4.80	15.0	25.2	6.60	26.0		
" 31......	26.2	4.2	20.0	25.2	7.2	20.0	25.3	4.2	21.0	25.6	3.60	21.4	25.7	3.60	22.6	25.7	2.50	23.9		
Jul. 6......	22.0	50.4	19.0	19.6	48.0	20.2	18.9	30.0	21.2	18.1	2.22	22.5	18.0	18.00	23.4	18.0	24.50	25.8	A6	Plowed 10 inches.
" 20......	20.5	20.4	21.2	21.0	13.2	23.0	20.9	27.6	23.6	20.8	10.80	23.2	20.4	4.80	24.3	19.9	6.00	24.6		
Aug. 3......	20.6	10.2	20.0	24.3	7.2	20.1	22.7	10.8	23.0	22.7	8.40	23.4	22.5	7.20	24.0	22.4	3.00	25.1		
" 17......	26.3	9.0	20.0	26.2	3.6	21.0	25.8	3.6	26.0	24.5	3.00	24.0	24.3	6.60	23.9	24.2	.32	25.0		
" 31......	26.2	8.0	20.0	25.2	3.5	21.2	25.3	3.5	22.0	25.6	2.90	23.0	25.0	6.50	23 7	25.7	.30	24.0		

x=spreading growth.

TABLE VI—PLOT A (sandy loam). Plowed March 18 and June 20. Number of bacteria per cubic centimeter, per cent. of moisture, depth in inches, and temperature.

DATE.	Second inch.			Fourth inch.			Sixth inch.			Eighth inch.			Tenth inch.			Twelfth inch.			Plot.	Treatment.
	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.		
Jul. 6......	22.0	24.6	20.0	19.6	19.8	21.2	18.9	36.6	22.4	18.1	20.2	23.0	18.0	9.60	23.00	18.0	3.60	23.0	A1	Undisturbed.
" 20......	20.5	25.2	24.8	21.0	20.4	24.3	20.9	19.2	26.0	20.8	14.4	28.3	20.4	10.80	25.80	19.9	.60	28.5		
Aug. 3......	25.6	16.8	21.0	24.3	13.2	20.0	22.7	7.2	21.0	22.7	9.6	21.0	22.5	2.40	21.00	23.4	.74	22.0		
" 17......	26.3	9.0	20.0	26.2	15.6	23.0	25.8	11.4	24.0	24.7	10.2	23.0	24.3	2.40	24.00	24.2	1.80	25.0		
" 31......	26.2	6.6	24.0	25.2	5.4	20.0	25.3	5.4	21.0	25.6	6.0	21.0	25.7	2.40	24.00	25.7	1.80	23.0		
Jul. 6......	22.0	27.6	21.6	19.6	16.2	22.0	18.9	18.6	25.0	18.1	18.6	25.5	18.0	15.60	25.70	18.0	5.40	26.8	A2	Plowed 2 inches.
" 20......	20.5	21.8	24.8	21.0	24.0	28.0	20.9	12.0	28.0	20.8	6.0	26.0	20.4	3.60	26.10	19.9	3.60	25.8		
Aug. 3......	25.6	9.6	20.0	24.3	8.4	20.0	22.7	12.0	20.0	22.7	15.6	22.0	22.5	3.60	22.00	22.4	1.60	24.0		
" 17......	26.3	13.2	25.0	26.2	11.4	24.0	25.8	10.2	24.0	24.7	5.4	26.0	24.3	3.40	26.00	24.2	2.40	28.0		
" 31......	26.2	8.4	18.0	25.2	6.6	21.0	25.3	5.4	22.0	25.6	9.6	25.0	25.7	3.00	24.00	25.7	.26	26.0		
Jul. 6......	22.0	22.8	18.8	19.6	19.8	21.0	18.9	13.2	22.5	18.1	16.2	23.0	18.0	7.80	24.80	18.0	1.80	25.1	A3	Plowed 4 inches.
" 20......	20.5	12.0	26.3	21.0	32.4	26.6	20.9	13.2	25.7	20.8	8.4	26.2	20.4	6.00	25.50	19.9	2.40	25.2		
Aug. 3......	25.6	6.0	21.0	24.3	8.4	23.4	22.7	7.2	24.9	22.7	5.4	25.0	22.5	1.20	26.00	22.4	2.40	24.9		
" 17......	26.3	6.0	20.0	26.2	4.8	23.0	21.3	10.2	24.9	24.2	3.0	24.3	24.3	.46	25.90	24.2	.66	26.0		
" 31......	26.7	6.6	23.0	25.2	3.0	19.0	25.3	3.6	23.0	25.6	4.0	23.4	25.7	.30	26.00	21.7	.30	25.4		
Jul. 6......	22.0	15.0	22.3	19.6	15.6	22.9	18.9	21.6	25.4	18.1	16.2	26.5	18.0	5.40	25.70	18.0	4.80	27.0	A4	Plowed 6 inches.
" 20......	20.5	20.4	27.5	21.0	27.6	27.0	20.9	46.8	26.5	20.8	lost	25.8	20.4	8.40	25.00	19.9	4.80	25.4		
Aug. 3......	25.6	11.4	21.0	24.3	9.6	22.0	22.7	13.2	22.9	22.7	12.6	23.0	22.5	.46	23.70	22.4	2.40	25.0		
" 17......	26.3	13.2	24.0	26.5	6.6	24.5	25.8	12.6	24.4	24.7	7.8	25.9	24.3	4.20	26.30	24.2	3.00	26.0		
" 31......	26.2	6.1	17.0	25.2	6.1	22.0	25.3	8.4	23.4	25.6	3.0	25.2	25.7	3.00	25.00	21.7	5.00	27.0		
Jul. 6......	22.0	46.2	19.2	19.6	24.6	22.2	18.9	15.6	24.0	18.1	19.2	24.9	18.0	10.80	25.10	18.0	4.80	26.0	A5	Plowed 8 inches.
" 20......	20.5	15.6	25.7	21.0	14.4	25.0	20.9	26.4	26.0	20.8	31.2	25.9	20.4	12.00	26.10	19.9	1.20	27.3		
Aug. 3......	25.6	3.6	19.0	24.3	23.4	26.7	22.7	7.8	25.8	22.7	10.8	26.0	22.5	15.00	27.04	22.4	6.00	27.1		
" 17......	26.3	12.0	20.0	26.5	3.6	21.3	25.8	9.6	22.1	24.7	6.0	25.0	24.3	6.60	26.20	24.2	4.20	26.0		
" 31......	26.2	8.4	24.3	25.2	4.9	25.0	25.3	6.0	25.0	25.6	7.8	26.1	25.7	4.80	24.80	21.7	1.80	23.2		
Jul. 6......	22.0	19.2	19.6	19.6	17.4	22.1	18.9	9.6	22.9	18.1	16.8	23.7	18.0	7.20	23.10	11.8	8.40	24.2	A6	Plowed 10 inches.
" 20......	20.5	12.0	25.4	21.0	14.4	24.6	20.9	19.2	24.9	20.8	4.2	26.9	20.4	13.20	20.20	19.9	8.40	26.5		
Aug. 3......	25.6	4.2	19.0	24.3	4.8	21.0	22.7	7.8	22.4	22.7	5.4	23.0	22.5	6.00	24.00	22.3	6.00	25.0		
" 17......	26.3	4.8	20.0	26.5	10.8	21.4	25.8	8.4	22.0	24.7	4.8	24.0	24.3	9.60	24.30	24.2	4.80	25.2		
" 31......	26.2	7.2	20.0	25.2	7.2	21.0	25.3	6.0	21.5	25.6	6.0	25.0	25.7	5.40	24.00	21.7	4.20	25.2		

TABLE VII—PLOT B (silt loam). Plowed March 18. Number of bacteria per cubic centimeter, per cent. of moisture, depth in inches, and temperature.

DATE.	Second inch.			Fourth inch.			Sixth inch			Eighth inch.			Tenth inch.			Twelfth inch.			Plot.	Treatment.
	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.		
Jul. 9..	25.4	25.20	17.0	23.1	36.0	17.9	22.9	8.40	19.0	22.3	2.40	20.0	21.9	2.40	20.0	21.0	7.20	23.0	B1	Undisturbed.
" 23..	28.0	4.80	18.0	26.0	13.2	18.4	24.9	.30	19.0	24.9	2.40	19.9	25.0	.10	26.0	24.7	.18	25.0		
Aug. 6..	28.6	2.40	20.0	27.3	1.8	20.9	26.7	.40	24.0	26.8	.24	26.8	24.0	.02	26.9	26.6	.02	26.0		
" 20..	21.3	7.20	26.0	20.2	4.8	26.4	19.8	6.00	26.8	19.7	3.00	27.0	20.3	6.00	27.2	20.3	1.80	27.0		
Sep. 3..	22.0	10.20	26.0	20.0	5.4	27.0	20.7	15.60	27.0	20.9	4.20	29.0	21.8	2.40	20.9	22.0	1.80	23.0		
Jul. 9..	25.4	18.00	25.0	23.1	40.8	25.0	22.9	19.20	27.0	22.3	4.80	27.4	21.9	4.80	27.8	21.0	2.80	26.9	B2	Plowed 2 inches.
" 23..	28.0	.84	10.0	26.0	4.8	24.6	24.9	4.80	13.0	24.9	.12	16.0	25.0	3.00	17.0	24.7	.08	11.0		
Aug. 6..	28.6	.38	15.0	27.3	.7	18.0	26.7	.14	20.0	26.8	.18	23.0	26.9	.08	20.0	26.6	.02	21.0		
" 20..	21.3	6.00	23.0	20.2	6.6	lost	19.8	5.40	20.0	19.7	.26	20.0	20.3	.38	19 0	20.3	.38	26.0		
Sep. 3..	22.0	4.80	18.0	20.0	7.2	21.0	20.7	5.40	lost	20.9	6.00	20.0	21.8	4.80	22.0	22.0	.18	16.0		
Jul. 9..	25.4	19.20	18.0	23.1	15.6	20.0	22.9	7.20	19.0	22.3	7.20	17.0	21.9	4.80	20.0	21.0	3.60	26.0	B3	Plowed 4 inches.
" 23..	28.0	6.00	15.4	26.0	10.0	17.0	24.9	.04	17.0	24.9	.06	11.0	25.0	.00	11.0	24.7	.01	29.0		
Aug. 6..	28.6	3.60	18.0	27.3	4.2	17.0	26.7	.28	20.0	26.8	.68	21.0	26.9	.58	21.0	26.6	.08	28.0		
" 20..	21.3	14.40	23.0	20.2	16.8	17.6	19.8	.60	19.0	19.7	.16	22.0	20.3	1.12	23.0	20.3	.21	21.0		
Sep. 3..	22.0	7.20	18.0	20.0	6.0	20.0	20.7	10.80	19.0	20.9	3.60	17.0	21.8	3.60	20.0	22.0	.12	26.0		
Jul. 9..	25.4	3.60	16.0	23.1	28.8	20.0	22.9	24.00	17.0	22.3	3 60	21.0	21.9	4.20	18.0	21.0	1.20	22.0	B4	Plowed 6 inches.
" 23..	28.0	6.00	18.2	26.0	6.0	17.0	24.9	3.60	12.0	24.9	.16	15.0	25.0	.08	15.0	24.7	.03	11.0		
Aug. 6..	28.6	.18	22.0	27.3	1.8	19.0	26.7	4.20	20.0	26.8	.02	18.0	26.9	.24	20.0	26.6	.06	23.0		
" 20..	21.3	5.40	21.0	20.2	11.4	27.0	19.8	4.80	22.0	19.7	.36	23.0	20.3	.18	18.0	20.3	.62	23.0		
Sep. 3..	22.0	5.40	16.0	20.0	10.8	20.0	20.7	8.40	17 0	20.9	4.80	21.0	21.8	3.60	18.0	22.0	3.60	22.0		
Jul. 9..	25.4	30.00	16.0	23.1	30.0	17.0	22.9	4.20	22.0	22.3	8.40	20.7	21.9	6.00	19.0	21.0	4.80	22.0	B5	Plowed 8 inches.
" 23..	28.0	.04	20.0	26.0	4.8	13.0	24.9	48.00	18.2	24.9	3.60	10.0	25.0	.06	10.0	24.7	.04	12.0		
Aug. 6..	28.6	2.40	19.0	27.3	2.4	18.0	26.7	3.00	19.0	26.8	.16	19.0	26.9	2.40	17.0	26.6	1.80	21.0		
" 20..	21.3	6.00	21.0	20.2	30.6	22.0	19.8	10.20	28.0	19.7	3.00	23.0	20.3	2.22	24.0	20.3	.34	23.0		
Sep. 3..	22.0	7.80	16.0	20.0	9.0	17.0	20.7	4.80	20.0	20.9	3.00	20.7	21.8	3.00	19.0	22.0	3.00	22.0		
Jul. 9..	25.4	26.40	19.0	23.1	33.6	20.0	22.9	34.80	20.0	22.3	27.60	20.0	21.9	7.20	20.0	21.0	4.80	22 0	B6	Plowed 10 inches.
" 23..	28.0	2.40	19.0	26.0	2.4	13.0	24.9	3.60	15.0	24.9	.32	18.0	25.0	.10	19.4	24.7	.12	20.4		
Aug. 6..	28.6	1.80	19.0	27.3	6.0	20.0	26.7	1.00	18.0	26.8	.12	19.0	26.9	.06	23.0	26.6	.44	21.0		
" 20..	21.3	6.60	20.2	20.8	10.7	17.0	19.8	4.20	17.0	19.7	4.80	20.3	20.3	3.00	23.0	20.3	1.80	24.0		
Sep. 3..	22.0	4.80	19.0	20.0	7.3	20.0	20.7	4.20	20.0	22.9	5.40	20.0	21.8	4.20	20 0	22 0	2.40	22.0		

TABLE VIII—Plot B (silt loam). Plowed March 18 and June 20. Number of bacteria per cubic centimeter, per cent. of moisture, depth in inches, and temperature.

Date.	Second inch.			Fourth inch.			Sixth inch.			Eighth inch.			Tenth inch.			Twelfth inch.			Plot.	Treatment.
	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.		
Jul. 9..	25.4	31.2	17.0	23.1	38.40	17.0	22.9	13.20	17.0	22.3	8.40	19.0	21.9	9.60	20.0	21.0	4.80	23.0	B1	Undisturbed.
" 23..	28.0	6.0	12.0	26.0	7.20	18.4	24.8	.30	19.0	24.9	3.60	18.0	25.0	3.60	26.0	24.7	.10	25.0		
Aug. 6..	28.6	2.4	16.0	27.3	1.80	19.0	26.7	.40	24.0	26.8	.24	21.0	26.9	.02	20.0	26.6	.02	24.0		
" 20..	21.3	7.2	26.0	20.2	4.80	21.0	19.8	6.00	25.0	19.7	3.00	20.0	20.3	6.00	26.0	20.3	1.80	25.0		
Sep. 3..	22.0	10.2	11.0	20.0	5.40	17.0	20.7	15.60	17.0	20.9	4.20	19.0	21.8	2.40	20.0	22.0	1.80	23.0		
Jul. 9..	25.4	16.8	18.0	23.1	26.46	15.1	22.0	19.20	15.2	22.3	4.80	20.0	21.9	2.40	22.0	21.0	2.40	16.0	B2	Plowed 2 inches.
" 23..	28.0	13.2	10.0	26.0	7.20	24.6	24.9	2.00	13.0	24.9	.30	16.0	25.0	.12	17.0	24.7	.16	11.0		
Aug. 6..	28.6	3.8	15.0	27.3	7.00	18.0	26.7	.14	20.0	26.8	1.80	23.0	26.9	.08	20.0	26.6	.08	21.0		
" 20..	21.3	6.0	23.0	20.0	6.60	19.0	19.8	5.40	20.0	19.7	.26	20.0	20.3	.38	19.0	20.3	.38	26.0		
Sep. 3..	22.0	4.8	18.0	20.0	7.20	15.1	20.7	5.40	lost	20.9	6.00	20.0	21.8	.48	22.0	22.0	1.80	16.0		
Jul. 9..	25.4	26.4	17.0	23.1	30.00	20.0	22.9	7.20	21.0	22.3	6.00	20.0	21.9	3.60	28.0	21.0	.60	23.0	B3	Plowed 4 inches.
" 23..	28.0	6.0	13.6	26.0	9.60	13.7	24.9	.16	23.0	24.9	12.00	13.8	25.0	.36	12.0	24.7	.02	18.0		
Aug. 6..	28.6	13.2	19.0	27.3	.28	14.0	26.7	.30	18.0	26.8	.58	26.0	26.9	.20	19.0	26.6	.72	22.0		
" 20..	21.3	10.2	18.0	20.2	18.00	20.0	19.7	14.40	23.0	19.7	4.80	23.0	20.3	3.60	23.0	20.3	.30	23.0		
Sep. 3..	22.0	7.2	18.0	20.0	10.80	17.0	20.7	4.20	21.0	20.9	5.40	23.0	21.8	3.60	23.0	22.0	4.80	23.0		
Jul. 9..	25.4	39.6	16.0	23.1	40.80	18.0	22.9	7.20	20.0	22.3	4.80	20.0	21.9	2.40	19.0	21.0	.60	20.0	B4	Plowed 6 inches.
" 23..	28.0	3.6	16.0	26.0	19.20	25.0	24.9	.08	15.0	24.9	2.40	19.0	25.0	.08	21.0	24.7	.30	14.2		
Aug. 6..	28.6	7.2	16.0	27.3	6.00	20.0	26.7	.96	23.0	26.8	.40	18.0	26.9	.04	22.0	26.6	.12	21.0		
" 20..	21.3	18.2	21.0	20.2	17.40	25.0	19.8	11.40	21.0	19.7	4.20	16.0	20.3	1.80	23.4	20.3	1.40	24.0		
Sep. 3..	22.0	7.2	19.0	20.0	12.00	21.0	20.7	4.80	lost	20.9	2.40	25.0	21.8	3.60	22.9	22.0	3.00	23.0		
Jul. 9..	25.4	16.8	18.0	23.1	27.60	17.0	22.9	10.80	21.0	22.3	7.20	23.0	21.9	1.20	23.0	21.0	2.40	23.0	B5	Plowed 8 inches.
" 23..	28.0	6.0	24.0	26.0	8.40	22.0	24.9	7.20	18.0	24.9	3.60	15.0	25.0	.14	18.0	24.7	.02	23.0		
Aug. 6..	28.6	4.8	20.0	27.3	3.60	29.0	26.7	18.00	18.0	26.8	.32	16.0	26.9	.04	21.0	26.6	.08	21.0		
" 20..	21.3	9.6	29.0	20.2	18.60	24.0	19.8	11.40	23.0	19.7	.12	27.0	20.3	.30	27.0	20.3	1.20	25.0		
Sep. 3..	22.0	4.8	17.0	20.0	5.40	20.0	20.7	6.60	21.0	20.9	9.00	20.0	21.8	10.20	24.0	22.0	7.20	23.0		
Jul. 9..	25.4	21.6	19.0	23.1	33.60	21.0	22.9	15.60	20.0	22.3	7.20	25.0	21.9	7.00	22.0	21.0	3.60	23.0	B6	Plowed 10 inches.
" 23..	28.0	6.0	24.0	26.0	4.80	18.0	24.9	3.60	15.0	24.9	.04	10.0	25.0	.04	21.0	24.7	.04	12.0		
Aug. 6..	28.6	3.6	15.0	27.7	4.80	18.0	26.7	3.60	18.0	26.8	7.20	18.0	26.9	5.40	20.0	26.6	1 20	19.0		
" 20..	21.3	5.4	28.0	20.2	9.60	28.0	19.8	10.20	23.0	19.7	14.40	28.0	20.3	8.40	25.0	20.3	2.40	26.0		
Sep. 3..	22.0	7.8	16.0	20.0	7.20	18.0	20.7	9.60	20.0	20.9	8.40	20.0	21.8	4.80	19.0	22.0	.30	20.0		

A COMPARISON OF THE GRAVIMETRIC AND VOLUMETRIC METHODS.

Tables I to IV give the comparative results obtained by gravimetric and volumetric methods. The samples were taken by means of the sampler described above. One cubic centimeter of soil was taken each time, placed in a sterile test-tube and weighed on an analytic balance. In every case duplicate samples were obtained and analyzed. In the following tables the weight of each sample is given in the first column, the number of bacteria per cubic centimeter is given in the second, and the number of bacteria per gram is given in the third column.

A glance at tables I to IV will show a variation in weights of samples varying in table I from 1.19 to 1.4 grams per cubic centimeter, from 0.965 to 1.14 grams in table II, from 1.021 to 1.232 grams in table III, and from 1.01 grams to 1.035 grams in table IV. The comparison also shows remarkable differences in weight between many samples and their duplicates, which were taken side by side. For instance, in table IV the fourth inch gives 1.01 grams while the duplicate gives 1.034. In the sandy soil (table II) the difference becomes more marked, showing in the twelfth inch a difference of 0.113 of a gram.

In tables I to IV the number of bacteria per cubic centimeter and per gram shows, in duplicate samples of soil, variations which are somewhat proportionate to the variations in weight of samples. These variations in quantitative findings represent the inaccuracy which is due to the volumetric method of taking soil samples. It may be assumed that such variations or inaccuracies will always occur from soil samples which are measured in terms of cubic centimeters. However, in general comparative soil bacteriological work these variations in number of bacteria, due to the volumetric method of procedure, may not be greater than those variations which might occur as a result of differences in specific gravities of different samples of soil, should the soil samples be taken by the gravimetric method. For instance, two types of soil, Marshall silt loam and sandy loam, were used in this work. The volume weight of the silt loam soil is 1.11 and the volume weight of the sandy loam is 1.35. Their weights stand in the ratio of 1:1.21; that is, an acre-foot of the sandy loam weighs 1.21 times as much as an acre-foot of the silt loam. Therefore, should samples be collected from the above types of soil by the gravimetric method and the comparative results expressed as so many bacteria per gram, the number of bacteria in an acre-foot of the sandy loam would in reality be compared with the number of bacteria in 1.21 acre-feet of the silt loam.

In quantitative bacteriological work, when comparative results are desired, the volumetric method has the following possible advantages over the gravimetric method:

1. It is more convenient.
2. It allows less chance for contamination.
3. It represents more accurately an aliquot part of an acre-foot of soil.

The last advantage appears to be true because of the difference in specific gravity of soils.

Drying Effect.—When we compare tables I and II with III and IV, we find no appreciable difference in results between those soil samples which were allowed to dry twenty-four hours before inoculation and those from which inoculations were made immediately after collection.

TABLE IX—PLOT A. Summarized total number bacteria given in table V.

DEPTH.	A1. Undisturbed.	A2. Plowed 2 in.	A3. Plowed 4 in.	A4. Plowed 6 in.	A5. Plowed 8 in.	A6. Plowed 10 in.
2 inches	43.80	72.00	53.40	44.40	72.00	98.00
4 "	58.80	57.40	43.20	68.40	80.40	75.50
6 "	42.60	70.80	60.00	66.60	69.00	85.50
8 "	46.40	58.20	36.60	52.20	63.96	47.30
10 "	13.36	20.80	28.20	45.60	64.07	43.10
12 "	11.54	7.12	20.48	15.46	38.50	34.12
Totals	216.50	286.32	241.68	292.66	393.93	383.52

TABLE X—PLOT A. Summarized total number of bacteria given in table VI.

DEPTH.	A1. Undisturbed.	A2. Plowed 2 in.	A3. Plowed 4 in.	A4. Plowed 6 in.	A5. Plowed 8 in.	A6. Plowed 10 in.
2 inches	82.20	80.60	53.40	66.10	85.80	47.40
4 "	74.40	66.60	68.40	65.50	70.90	54.60
6 "	79.80	58.20	47.40	102.60	65.40	51.00
8 "	60.40	55.20	37.00	39.60	75.00	37.20
10 "	27.60	29.20	15.76	21.46	49.20	41.40
12 "	8.54	13.26	7.56	20.00	18.00	31.80
Totals	332.94	303.06	229.52	315.26	364.30	263.40

TABLE XI—PLOT B. Summarized total number bacteria given in table VII.

DEPTH.	B1. Undisturbed.	B2. Plowed 2 in.	B3. Plowed 4 in.	B4. Plowed 6 in.	B5. Plowed 8 in.	B6. Plowed 10 in.
2 inches	49.80	30.02	50.40	20.58	46.24	42.00
4 "	61.20	60.10	52.60	58.80	76.80	60.00
6 "	30.70	34.94	18.92	45.00	70.20	47.80
8 "	12.24	11.36	11.70	8.94	18.16	38.24
10 "	10.92	13.06	10.10	8.30	13.68	14.56
12 "	11.00	3.46	4.02	5.51	9.98	9.56
Totals	175.86	152.94	147.74	147.13	235 06	212.16

TABLE XII—PLOT B. Summarized total number bacteria given in table VIII.

DEPTH.	B1. Undisturbed.	B2. Plowed 2 in.	B3. Plowed 4 in.	B4. Plowed 6 in.	B5. Plowed 8 in.	B6. Plowed 10 in.
2 inches	57.00	44.60	63.00	70.80	42.00	44.40
4 "	57.60	54.40	68.68	95.40	63.60	60.00
6 "	35.50	32.14	26.26	24.44	54.00	42.60
8 "	19.44	13.16	28.78	14.20	20.24	37.24
10 "	21.62	3.46	11.36	7.92	11.88	25.64
12 "	8.52	4.82	6.44	5.42	10.90	7.54
Totals	199.68	152.58	204.52	218.18	202.62	217.42

TABLE XIII.

DATE.	Plot.	Ammonia, parts per million.	Nitrites, parts per million.	Gas production.		
				Glucose bouillon, in cc.	Lactose bouillon, in cc.	Saccharose bouillon, in cc.
Jul. 20	A1	25	75	0.00	0.00	0.0
" 20	A2	50	75	7.70	1.25	0.0
" 20	A3	50	75	4.50	1.75	0.9
" 20	A4	1	40	5.80	0.00	0.0
" 20	A5	75	1	5.80	0.00	0.0
" 20	A6	75	14	5.50	0.00	0.0
Totals	......	276	280			
Aug. 3	A1	50	45	0.00	0.00	0.0
" 3	A2	25	50	0.00	0.00	0.0
" 3	A3	250	75	0.00	0.00	0.0
" 3	A4	75	30	0.00	0.00	0.0
" 3	A5	45	40	0.00	0.00	0.0
" 3	A6	75	20	0.00	0.00	0.0
Totals	......	520	260			
Aug. 17	A1	30	145	3.00	1.50	5.5
" 17	A2	300	111	1.75	1.25	5.0
" 17	A3	1	x	3.00	1.75	7.0
" 17	A4	x	100	2.00	1.10	5.0
" 17	A5	300	x	2.50	1.00	7.0
" 17	A6	800	x	1.50	1.50	9.5
Totals	......	1,431	356			
Aug. 31	A1	700	200	7.50	8.50	0.0
" 31	A2	750	150	8.15	9.00	0.0
" 31	A3	1	75	6.00	2.50	0.0
" 31	A4	1,500	80	6,00	9.50	0.0
" 31	A5	1,000	65	2.50	.50	0.0
" 31	A6	2,000	110	8.50	1.50	0.0
Totals	......	5,951	680			

Total nitrites, 1576; total ammonia, 8178.

TABLE XIV.

DATE.	Plot.	Ammonia, parts per million.	Nitrites, parts per million.	Gas production.		
				Glucose bouillon, in cm.	Lactose bouillon, in cm.	Saccharose bouillon, in cm.
Jul. 20	A1	25	30	0.00	0.00	0.00
“ 20	A2	50	30	7.00	1.25	0.00
“ 20	A3	5	17	7.50	0.00	0.00
“ 20	A4	50	10	8.50	0.00	0.00
“ 20	A5	1	15	9.80	0.00	0.00
“ 20	A6	100	11	10.00	lost	0.00
Totals	......	231	113			
Aug. 3	A1	25	15	0.00	0.00	0.00
“ 3	A2	50	20	0.00	0.00	0.00
“ 3	A3	25	17	0.00	0.00	0.00
“ 3	A4	50	20	0.00	0.00	0.00
“ 3	A5	10	11	3.25	0.00	0.00
“ 3	A6	90	11	0.00	lost	3.00
Totals	......	250	94			
Aug. 17	A1	30	145	3.00	1.50	5.00
“ 17	A2	300	111	1.75	1.25	7.25
“ 17	A3	700	x	1.50	1.00	8.00
“ 17	A4	x	100	2.00	1.50	9.50
“ 17	A5	lost	x	1.00	1.25	10.00
“ 17	A6	800	x	1.50	1.00	10.00
Totals	......	1,830	356			
Aug. 31	A1	700	150	7.50	8.50	0.00
“ 31	A2	750	140	8.15	9.90	0.00
“ 31	A3	500	90	10.50	2.00	0.00
“ 31	A4	700	40	8.00	1.00	0.00
“ 31	A5	1,000	75	1.00	.50	0.00
“ 31	A6	950	30	10.00	9.50	0.00
Totals	......	4,600	525			

Total nitrites, 1088; total ammonia, 6911.

TABLE XV.

DATE.	Plot.	Ammonia, parts per million.	Nitrites, parts per million.	Gas production.		
				Glucose bouillon, in cm.	Lactose bouillon, in cm.	Saccharose bouillon, in cm.
Jul. 23	B1	25	15	0.00	0.00	0.00
" 23	B2	50	27	0.00	2.00	0.00
" 23	B3	100	20	4.00	3.00	0.00
" 23	B4	50	11	0.00	1.50	1.00
" 23	B5	50	12	1.00	5.00	0.00
" 23	B6	100	9	1.50	7.00	0.00
Totals		375	94			
Aug. 6	B1	x	17	4.25	1.75	7.25
" 6	B2	x	17	4.00	1.50	8.00
" 6	B3	1	10	4.25	1.20	7.50
" 6	B4	1	6	0.00	0.00	0.00
" 6	B5	1	2	0.00	1.25	0.00
" 6	B6	9	8	0.00	.50	7.70
Totals		12	60			
Aug. 20	B1	100	150	3.25	3.00	0.00
" 20	B2	300	145	0.00	0.00	0.00
" 20	B3	90	145	3.50	1.25	7.00
" 20	B4	400	x	0.00	0.00	0.00
" 20	B5	600	120	T	T	0.00
" 20	B6	x	75	0.00	0.00	0.00
Totals		1,490	635			
Sep. 3	B1	2,000	20	11.00	7.00	0.00
" 3	B2	0	25	7.00	4.00	0.00
" 3	B3	5,000	30	55.00	3.50	0.00
" 3	B4	6,000	4	8.50	4.00	0.00
" 3	B5	8,000	7	8.50	45.00	0.00
" 3	B6	6,000	2	12.00	8.50	0.00
Totals		27,000	88			

Total nitrites, 877; total ammonia, 28,877.

TABLE XVI.

DATE.	Plot.	Ammonia, parts per million.	Nitrites, parts per million.	Gas production.		
				Glucose bouillon, in cm.	Lactose bouillon, in cm.	Saccharose bouillon, in cm.
Jul. 23	B1	25	10	1.00	0.00	0.00
“ 23	B2	50	10	1.50	0.00	0.00
“ 23	B3	75	x	3.50	0.00	0.00
“ 23	B4	25	5	0.00	0.00	0.00
“ 23	B5	50	8	0.00	9.00	8.00
“ 23	B6	100	6	0.00	0.00	1.50
Totals		325	39			
Aug. 6	B1	x	15	4.25	1.75	7.25
“ 6	B2	x	16	4.00	1.50	8.00
“ 6	B3	1	9	4 25	1.00	9.40
“ 6	B4	4	11	3.75	1.40	8.40
“ 6	B5	x	4	4.00	1.50	5.75
“ 6	B6	10	7	4.10	1.00	8.75
Totals		15	62			
Aug. 20	B1	100	185	3 25	3.00	0.00
“ 20	B2	300	145	0.00	0.00	0.00
“ 20	B3	30	145	5.00	0.00	0.00
“ 20	B4	0	175	0.00	1.00	0.00
“ 20	B5	8	120	0.00	2.00	0.00
“ 20	B6	lost	90	0.00	0.00	0.00
Totals		438	860			
Sep. 3	B1	2,000	20	11.00	7.00	0.00
“ 3	B2	0	25	7.00	4.00	0.00
“ 3	B3	6,000	5	8.50	8.50	0.00
“ 3	B4	8,000	7	8.00	2.00	0.00
“ 3	B5	8,500	7	9.00	10.00	0.00
“ 3	B6	9,000	6	8 00	9.50	0.00
Totals		33,500	70			

Total nitrites, 1031; total ammonia, 34,278.

NUMBER OF BACTERIA.

Tables V to VIII show a great variation between the number of bacteria at the beginning of the experiment and at the close. This condition holds in all subplots in both sandy and silt loam soils. This may be due to the lessening amount of food available to the bacteria because the temperature, moisture and air remain throughout the experiment within the limit of experimental variation.

Tables V to VIII show exceptionally high numbers of bacteria, sometimes in the surface six inches, and again at the depth of twelve inches. The extra large numbers which are found in some samples from the first six inches of soil were nearly always attributable to manure or quantities of organic matter, while those in the subsoil were usually near some burrow, or at times were due to the presence of a heavy, decaying root.

By comparing tables I to X in the preliminary experiments (part I), it was found that the total number of bacteria in the surface foot of soil is increased by the deeper plowing. This fact is also shown in tables IX to XII (part II), which contain the sum totals of tables V to VIII. In the Marshall silt loam there was also a slight advantage in regard to the total number of bacteria in favor of the plots which were replowed on June 20.

AMMONIA PRODUCTION.

Tables XIII to XVI show the relative amounts of ammonia produced in the different plots. The total amount produced in the silt loam soil exceeded that produced in the sandy loam soil. A comparison of the tables will show that the amount of ammonia produced in the different plots, both in the sandy loam and the silt loam, increased with the depth of plowing. The depth of plowing seems to have greater effect upon the ammonia production in the more tenacious silt soil.

This increase in ammonia production was not regular, but in general conformed to the depth of stirring, although the amount produced varied greatly from week to week. Excess of moisture showed a tendency to lessen the amount of ammonia produced.

Occasionally only a trace of ammonia was present, as will be seen in table XIII, subplot A4, on July 20, and again in subplots A3 and A4, on August 17. This irregularity is found in all the plots. In many cases where these low yields occurred the medium was overgrown with an organism which produced a greenish pigment similar to that of *Ps. fluorescens liquefaciens.* These bacteria seemed to predominate during an excessively moist period.

REDUCTION OF NITRATES.

Denitrification, or the reduction of nitrates to nitrites, with the final liberation of nitrogen gas, may accompany the destructive processes of nitrogen compounds. Some of the ammonia compounds are broken down, liberating free nitrogen, while at the same time the nitrates which may have been formed are reduced to nitrites. These may be broken down into simpler substances, thus releasing free nitrogen.

The results of the experiments testing denitrification are given in tables XIII to XVI, under the heading "Nitrites," expressed as parts per million. In general, the amount of nitrites produced was in inverse proportion to the amounts of ammonia produced. In general, the production of nitrites decreased as the depth of plowing increased.

SUMMARY.

The results of these preliminary experiments suggest the following conclusions:

1. Deep plowing (eight to ten inches) tends to increase the number of soil bacteria in both sandy and silt soils.
2. Deep plowing tends to increase bacterial activity. More ammonia is produced.
3. Deep plowing tends to decrease denitrification or the reduction of nitrates and the liberation of free nitrogen.
4. The volumetric method of quantitative bacteriological soil analysis has the following possible advantages over the gravimetric method: (*a*) It is more simple and convenient; (*b*) there is less danger of contamination; (*c*) the results are placed on a more accurate basis for comparison. The volumetric method can be used to advantage when comparative results are desired.
5. Increased soil temperature increases bacterial activity.
6. An excess of moisture in soil reduces the number of bacteria and is detrimental to bacterial activity.
7. The maximum number of bacteria is found within the fifth and sixth inches. Either side of this zone the numbers of bacteria decrease.
8. Due to certain conditions, different species of bacteria are present in soil, at different times in predominating numbers.
9. Bacterial life and activity seem to rise and fall with more or less regularity. These periods of maximum and minimum activity are to a certain extent independent of moisture and temperature and are possibly due to the presence of bacterial by-products.

THE FOLLOWING BULLETINS

ARE AVAILABLE FOR DISTRIBUTION TO THOSE RESIDENTS OF KANSAS WHO MAY DESIRE THEM:

No. 12....Preliminary Experiments with Fungicides for Stinking Smut of Wheat.
No. 13....Experiments with Oats.
No. 15....Additional Experiments and Observation on Oat Smut.
No. 16....Experiments with Sorghum and with Sugar Beets.
No. 43....Experiments with Sorghum and with Sugar Beets.
No. 52....Kansas Weeds—Preliminary Circular on Distribution.
No. 120....Tests of Forest Trees.
No. 121....Treatment and Utilization of Flood-damaged Lands.
No. 122....Blackleg and Vaccination.
No. 129....Kansas Mammals in their Relation to Agriculture.
No. 136....Press Bulletins Nos. 125-151.
No. 137....Variations in the Test of Separator Cream.
No. 138....Effect of Bacteria in Wash-water of Butter.
No. 139....The Study of Corn.
No. 140....Milking Machines.
No. 141....Commercial Seeds of Brome-grass and of English and Kentucky Blue-grasses: Adulterants and Substitutes and their Detection.
No. 142....The Value of Oil in Road Improvement.
No. 143....Disposal of Dairy and Farm Sewage, and Water Supply.
No. 144....Small-grain Crops.
No. 145....Spraying.
No. 148....Law Regulating the Sale of Commercial Fertilizers.
No. 149....Prevention of Sorghum and Kafir-corn Smut.
No. 150....The Hen's Place on the Farm.
No. 151....Alfalfa Breeding.
No. 152....The Pocket Gopher.
No. 153....Deterioration of Red Texas Oats in Kansas.
No. 154....The Mound-building Prairie Ant.
No. 155....Alfalfa.
No. 158....Analyses of Registered Feeding Stuffs.
No. 159....Analyses of Eggs.
No. 160....Cow-peas.
Circular No. 1.—Treating Seed-corn to Protect it from Burrowing Animals.
Circular No. 2.—Preparing Land for Wheat.

The Bulletins of the Experiment Station are sent free to applicants. Farmers are invited to send the names of others who would value them and samples will be sent, with return cards upon which applications for future issues may be made.

Address: AGRICULTURAL EXPERIMENT STATION,
Manhattan, Kan.

Kansas State Agricultural College.

EXPERIMENT STATION.—Bulletin 168.

ED. H. WEBSTER, *Director*.

FARM BULLETIN.

Entomology and Zoology Department.

THOMAS J. HEADLEE, *Entomologist and Zoölogist in Charge.*

THE COMMON MOLE (*Scalops aquaticus*). Original.

The Common Mole.

BY

THEO. H. SCHEFFER, *Assistant in Zoology.*

MANHATTAN, KAN.
AUGUST 1, 1910.
3050

Kansas State Agricultural College.

AGRICULTURAL EXPERIMENT STATION.

Department of Entomology and Zoology.

T. J. HEADLEE	Entomologist and Zoölogist in Charge.
G. A. DEAN	Assistant in Mill and Grain Insect Investigations.
J. B. PARKER	Assistant in Field Insect Investigations.
L. M. PEAIRS	Assistant in Fruit Insect Investigations.
HARRY EVANS	Assistant in General Entomological Investigations.
THEO. H. SCHEFFER	Assistant in Zoölogical Investigations.

Work of the Department of Entomology and Zoology.

This department covers a wide field of usefulness to the farmers of Kansas. For two years there has been maintained a general field survey and extensive investigation of the ravages of field insects such as chinch bug, Hessian fly, green bug, corn ear-worm, and other insect pests of general agricultural crops. This work has been carried on in coöperation with farmers in various parts of the state. Instructions for combating these insects have been formulated and are sent to any one on request. Investigations as to the destructive tendencies of rodents are in progress. The eradication of insects in mills, elevators and granaries is being studied and is carried on in coöperation with mill owners, elevator men and farmers.

For three years destruction of San José scale, which is perhaps the most serious of deciduous fruit insects, has been carried forward under the entomological law of 1907 in coöperation with farmers and fruit growers. Plantings over 158 square miles have been examined, scale-infested plantings located, and the owners informed of the dangerous nature of the creature with which they had to deal. Methods by means of which the scale could be killed have been explained and arrangements made to carry out the necessary treatment. About 4000 owners and tenants have been personally visited one or more times. More recently other insects injurious to fruit, such as codling moth and plum curculio, have been taken into consideration, and extensive orchard-spraying experiments are now in progress in various parts of the state.

Bulletins, circulars, and press bulletins reporting progress and results of these studies are being issued from time to time and may be had by writing the Experiment Station.

Other Departments of the Station Are—

AGRONOMY	W. M. Jardine in charge.
ANIMAL HUSBANDRY	Roland J. Kinzer in charge.
BOTANY	Herbert F. Roberts in charge.
BACTERIOLOGY	——— ——— in charge.
CHEMISTRY	Julius T. Willard in charge.
DAIRY HUSBANDRY	——— ——— in charge.
FORESTRY	Chas. A. Scott in charge.
HORTICULTURE	Albert Dickens in charge.
MILLING INDUSTRY	Leslie A. Fitz in charge.
VETERINARY SCIENCE	F. S. Schoenleber in charge.

THE COMMON MOLE.

By Theo. H. Scheffer.

SUMMARY.

1. There seems to be but a single species of mole in Kansas. It is common in the eastern half of the state and abundant in the eastern third. In western Kansas the mole is entirely absent or found only occasionally along the watercourses.

2. The mole is not a social animal, being condemned to a solitary existence by the conditions under which he lives. Moles come out of the seclusion of their underground burrows only occasionally, as if by accident.

3. The mole's system of runways threads the soil everywhere in well watered regions. There are two parts to the system—the deeper burrows or highways leading to small underground chambers, and the shallow surface ridges ranging over the hunting grounds.

4. The mole thrives best in a loose, moist soil abounding in grubs and earthworms. It therefore frequents fields and woods shaded by vegetation, but is not able to maintain existence in the hard, compact soil of semiarid regions.

5. The mole does not hibernate, but is more or less active at all seasons of the year. During the rainy periods of summer his work is pushed the most vigorously.

6. The young of the mole are produced within a period of three to five weeks, mainly in March and early April. They number from three to five.

7. The labyrinth of tunnels constructed by the mole serves as passageways for several species of mice, which are alone responsible for most of the damage to seeds, roots, and tubers encountered in the soil.

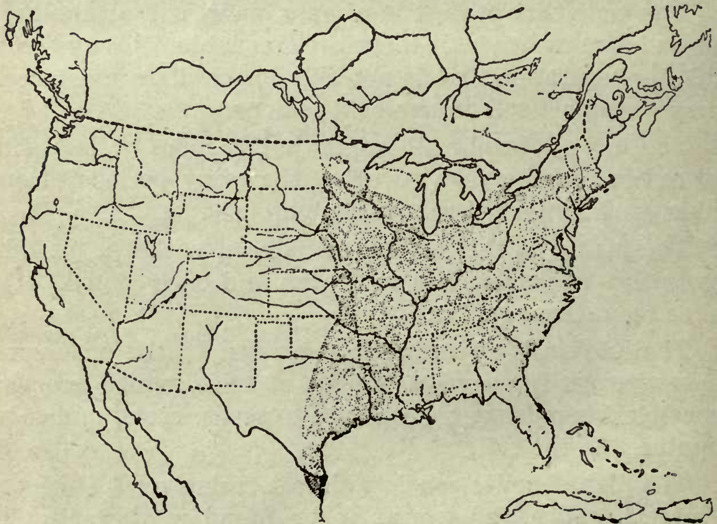
8. The diet of moles consists almost exclusively of the various insects, grubs and worms to be found in the soil. The amount of vegetable substance found in stomach examinations is usually no more than might have been taken in incidental to the ingestion of other food.

9. By reason of its secluded life underground, the mole has but few natural enemies. Coyotes, badgers and skunks dig out a few of them, and occasionally a hawk or owl surprises one aboveground. The flooding of lowlands during spring freshets is probably the greatest danger that menaces the adult mole and his progeny.

10. From the standpoint of food habits, and also in respect to tunneling the soil, the work of the mole is highly beneficial to the interests of agriculture. Moles should not be tolerated, however, in lawns, small garden plats and parks, because of the disfigurement and the injury to plant roots that result from their work.

11. The best method of combating the mole is by means of a trap in the hands of a person who knows how to set it. Crystals of strychnine in raisins or bits of fresh meat make fairly effective poison baits.

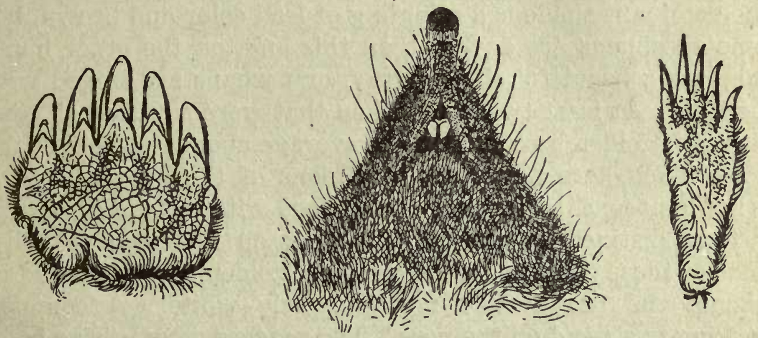
12. The mice which take seed corn in the ground may be destroyed by introducing poisoned grain baits into mole runways throughout the field. The theft of seed corn may sometimes be prevented by treating it with coal tar, tobacco decoction, or stock dip before planting.



Geographical distribution of the common mole (genus *Scalops*), shown by the shaded area. (From True's Revision of American Moles.)

DESCRIPTION AND DISTRIBUTION.

The mole which forms the subject of this discussion is usually referred to as the "common garden mole." It belongs to a genus (*Scalops*) which is distributed very generally over the eastern part of the United States and the Mississippi valley as far west as the plains. There is not enough variation in type over this range to establish more than a single species (*aquaticus*), but four or five subspecies are recognized. The Kansas mole has usually been assigned to the subspecies *machrinus*, but from the large number of specimens examined it seems best to place it in the subspecies *intermedius* of Elliott. Therefore it may be designated as *Scalops aquaticus intermedius*.



Hand, nose and foot of the common mole; under surface in each case. Original.

The true moles may be distinguished from meadow mice, shrews, or pocket gophers—with which they are often confused—by the following peculiarities: They have a naked, pointed snout extending nearly a half inch in front of the mouth opening, which is, therefore, ventral. The eyes are very minute and concealed in the fur. The same is true of the auditory orifice. There are no external ears. The fore feet are very large and broad, the palms being wider than long. The toes of the feet are webbed to the base of the claws, which are broad and depressed. The hind feet are small and narrow, with slender, sharp claws. The variation in size among individuals taken in the same locality is not especially marked, but it is more noticeable when comparing specimens taken in arid and in moist regions respectively.

The following data apply to the first 100 moles taken at Manhattan during the progress of these experiments:

AVERAGE DIMENSIONS AND WEIGHT.

Males (45 specimens):
  Average total length, 176 mm. (about 7 inches).
  Average length of tail, 30 mm. (about $1\frac{3}{16}$ inches).
  Average weight, 4 ounces.
Females (55 specimens):
  Average total length, 168 mm. (about $6\frac{5}{8}$ inches).
  Average length of tail, 30 mm. (about $1\frac{3}{16}$ inches).
  Average weight, 3 ounces.

In contrast to the slight variation in size among moles taken in the same locality is the marked variation in color. The dominant shade is a mingling of lead color and brown, but some specimens are darker than this and, on the other hand, some are a beautiful slivery gray, or perhaps are tinged with purplish. At least two were taken that were suffused all over with rich golden brown. On the average about one-half of the moles taken here have certain regions of the body—particularly the nose, chin and breast—washed with a tinge of orange or have distinct patches of this color on the head or belly. Some of these patches are yellowish or golden brown instead of orange, and occasionally one is nearly white. A common marking is a band on the nose. The patches vary in size from a mere streak to a blotch covering almost the entire area of the belly or head. The following data on color markings are from the same 100 moles discussed under the head of average dimensions and weight:

Males:	
Number having orange or rusty brown markings	27
Number marked on nose only	5
Number suffused or washed in part	18
Number having well-defined patches	6
Females:	
Number having orange or rusty brown markings	23
Number marked on nose only	12
Number suffused or washed in part	2
Number having well-defined patches	9

The distribution of moles seems to depend very largely upon the humidity of the climate and consequent condition of the soil in any particular region. As will be shown later, the mole thrives best in a loose, moist soil, abounding in grubs and earthworms. The hard, compact surface earth of arid and semiarid regions is not at all inviting to an animal that must make its living by plowing along beneath the feet of the more favored creatures that crop the grass. Though able, perhaps, to burrow wherever an earthworm can burrow, the mole could not thrive and maintain its numbers in regions where these worms were few and small in size.

The accompanynig map (page 2) gives the distribution of the genus *Scalops*. Two other genera—*Condylura* and *Parascalops*—occupy portions of this same territory. Between the shaded area on the map and a narrow strip bordering the Pacific coast there are said to be no moles. This statement must be taken with some reservation, however, for moles are found in decreasing numbers on the lowlands along the watercourses as far west at least as the one hundred and first meridian. On a recent trip through the western part of Kansas, careful search was made for evidences of moles in favorable spots along the Saline, the Smoky Hill and the Arkansas rivers and their tributaries. At Wilson, on the Saline, moles were fairly common in cultivated fields and gardens. They were also reported from the Station grounds at Hays. At Oakley, no traces of the animal could be found, nor did inquiry among the residents show that one had ever been seen there. Along the Smoky Hill it was learned that moles have been taken occasionally as far west as Logan county, but no traces of their work were found. Residents along the river at Wallace assert that there are no moles in the country. At Garden City, on the Arkansas, moles were sufficiently numerous to be troublesome in lawns. A specimen taken at Great Bend did not seem to differ in any respect from those collected at Manhattan.

ACTIVE PERIODS.

WET AND DRY PERIODS. The mole does not hibernate. Like the pocket gopher, he is more or less active at all seasons of the year. It is during the rainy periods, however, when the soil is moist quite to the surface, that his work is pushed the most vigorously. Shallow runways are then rapidly extended in all directions, and old runways repaired. When, later, the ground becomes dry and hard, extensions to the system of tunnels are made only in shaded spots, in cultivated fields, or in other favored areas where for some reason or other the soil has become less compact. When a mole chooses to go in a certain direction, however, nothing but concrete or stone will stop him. The strength of the little animals is marvelous. They will heave up the surface of a path trodden so hard that repeated blows of a pick would be required to break the crust. In like manner the bricks of a sidewalk are pushed up out of place, and on one occasion a run was noticed heaved up across the hard, baked roadway over which a heavy traction engine frequently passed.

THE FALL SEASON. In the late fall one will observe an increasing number of the little mounds of earth often associated with a system of mole runways. The presence of these indicates active operations in some of the deeper parts of the system. Ordinarily a mole makes his way through the soil much as a root does, or a stake when driven by the blows of a sledge. The earth is not excavated, but simply crowded aside. This is true of the work even at considerable depths when the soil is moist. But when the ground becomes harder, as it usually does in the autumn, the mole is obliged to excavate the passageways with his stout front feet and dispose of the loose earth by pushing it out through openings in the roof of his surface tunnels.

IN WINTER. At any time in winter when the ground is not frozen too hard, the mole keeps up his work. During the freezing days of January observations have shown fresh burrows ridging up a hard crust of snow covering a thin layer of frozen soil. There seems to be no good reason for assuming, as some do, that during hard freezing weather the mole keeps burrowing away beneath the frost line. He could not make his way at this depth by compacting the soil, and observations have not shown loose earth brought to the surface at such times. Again there would be no need to carry on burrowing operations under such unfavorable conditions. The system of passages already constructed could be retraversed in search of food until opportunity offered for extending it. Worms and hibernating insects are just as likely to be found in a passageway the second or third time it is traversed as they were when it was being constructed, for many of these little creatures of the soil are on the move also.

FOOD STORAGE. Owing to the peculiar character of a mole's diet, storage of food for an unfavorable period or season would seem out of the question. There seems to be no indications that supplies are thus laid up for a "rainy day." A

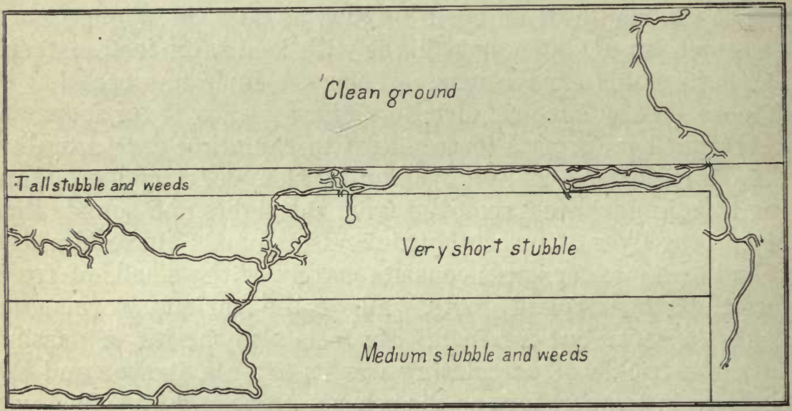
French writer avers that the common European mole stores earthworms, first biting off their heads so they cannot escape. Such a trifling thing as the loss of a head would not hinder our American earthworms from making their escape tail first.

WORKING HOURS OF THE DAY. It seems to be a matter of common observation that the mole can be found at work more frequently in the morning and evening than at any other time of day. Some observers also state that there is a third period of activity, between eleven and twelve o'clock, noon. This statement has not been verified by these observations.

HABITS.

GENERAL. Like the various species of pocket gophers that inhabit the prairies and plains, the mole lives in the seclusion of underground burrows, coming to the surface only by accident. He does not even permit himself the diversion of an airing at the mouth of an open burrow, as does the gopher when he comes out at dawn or twilight with load after load of fresh earth from his excavations. When the mole has occasion to dispose of any surplus dirt he simply pushes it up from beneath until it forms a loose pile with radiating cracks, unlike the dump formed coal-pit fashion by the pocket gopher. Living thus in darkness, removed from the sights and sounds that attend the lives of insects, birds and mammals above him, the round of his experiences consists mainly of the smells of fresh moist earth, of plant roots, and of the various worms and grubs he seeks out for food. He feels also the jar of passing feet, the trickle of percolating waters after a shower and the changes in temperature as the seasons come and go. Observations have led us to believe that the mole is not a social animal—that the very character of his environment compels him to lead the life of a hermit. This must necessarily be the case with any animal that spends all of its time underground. It is true that on several occasions two or even three moles have been trapped at the same spot, but that need not lead to the inference that they had lived together in a social way in that particular burrow. In soil ridged up by a labyrinth of runways frequent intersections of separate burrows must necessarily result.

THE RUNWAY. After following along the devious course of a mole's path, just beneath the surface of the ground, one will find sooner or later that it begins to run slightly deeper in a certain direction. Approaching from another quarter of the infested plat the surface runway will again be found to turn downward somewhere in the same direction as before. These deeper runs are the highways leading from the mole's home to his hunting grounds. In fact, they may be said to constitute a part of his permanent residence, although the home proper is an irregular chamber here and there connected with these runs. The latter follow a course from five to seven or eight inches beneath the surface of the ground—deeper than the soil is usually stirred by agricultural operations. The chambers from which these runs radiate are not large, their average capacity being about a quart. These investigations have never revealed any nesting material in them. The American genera of moles do not construct "mole hills," as the European genus *Talpa* is said to do.



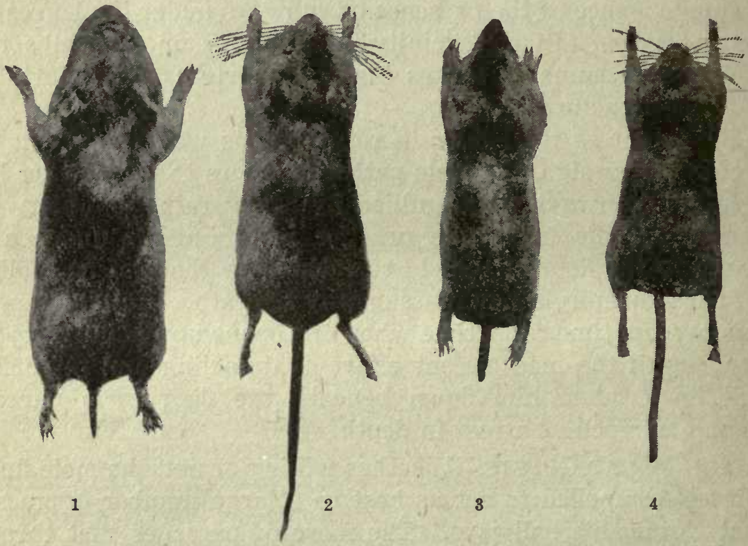
Plot of ground in which a mole runway was excavated. The total length of the parts of the runway shown was 475 feet. The deeper parts of the runway are just to the left of the center of the illustration. Several small chambers were found in this part of the system.

By far the greater extent of a mole's system of runways is made up of the shallow burrows ranging over his hunting grounds. These are merely subsurface paths pushed hither and thither by the vigorous little animal in his search for food. They may not be used again or they may be retraversed at irregular intervals. After a time they become filled up by the settling of the soil above, especially after heavy showers. In some cases, also, the mole evidently pushes into them the dirt which he has excavated in his deeper runways. These subterannean hunting paths are about an inch and a quarter to an inch and a half in diameter. They usually ridge up the surface of the soil so that their course can be readily followed. In wet weather they are very shallow; during a dry period they range somewhat deeper, following the course of the earthworm.

HABITAT. While the mole seeks out the higher and dryer spots for his home and his highways, he hunts preferably in soil that is shaded, cool and moist. Here worms and grubs abound, and these favored areas soon become traversed by a perfect labyrinth of subsurface paths. This accounts for the persistency with which moles stick to our lawns and parks. In neglected orchards and natural wood-lands, where the mole works undisturbed, the ground yields everywhere to the tread, giving evidence of the presence of runways under the leaves or matted grass. In the vicinity of buildings or sidewalks the mole very commonly makes his headquarters under portions of these structures.

Persistent as the spider in repairing its web when torn by accident or design, the mole patiently labors to reconstruct his principal runways when gullied by heavy rains or otherwise damaged. His invariable practice is to burrow under and heave up the floor of the old run wherever the roof has fallen in, thus forming a new passageway beneath. He will repeat this process time after time when one opens up his burrows by hand, until the most recent effort at tunneling and repairing will have taken him down beneath the floor of a narrow trench as much as a foot in depth.

THE MOLE'S GUESTS. Whether willing or not, the mole finds himself compelled to act as host to a large number of guests that throng his hallways. The maze of passages that thread the soil everywhere furnishes concealment and lines of traffic to several species of small mammals not favored by nature with the means for digging runways of their own. What the mole's attitude towards each species of these intruders may be these investigations have not revealed. In the case of the shrew it would seem to be one of hostility, for the shrew and the mole are on the lookout for the same kinds of food. The shrew is generally supposed to do some burrowing on his own account, but any number of the little animals have been trapped in runways that from their size and general appearance were undoubtedly constructed by moles. In fact, observations more than once showed a trap holding a dead shrew pushed up by fresh mole work almost out of the small excavation that had been made. Whether tolerated or not, the shrew by no act contributes to blackening the reputation of his host as do the other guests—mainly voles (meadow mice), white-footed field mice and the common house mouse. These latter are directly responsible for most of the thefts of grains, seeds and tubers commonly laid to the charge of the mole. Conclusive evidence of the truth of this statement will be found in another part of this bulletin. It is sufficient to state here that the presence of these little rodent pests in considerable numbers in the mole's runways can easily be demonstrated by the use of small traps.



The Mole's Guests. (Original.) 1—Meadow mouse (*Microtus*). 2—White-footed mouse (*Peromyscus*). 3—Shrew (*Blarina*). 4—Common house mouse (*Mus musculus*).

BREEDING. Though one of the most abundant of our small mammals, the mole is a slow breeder. This would be expected of an animal withdrawn from the strife and competition that reddens tooth and claw in the world above his secluded burrows. As will be seen from the accompanying table, the number of young at a birth is normally four and but one litter is produced annually. These facts were ascertained from the examination of a large number of females (101) taken in all months of the year. Thirty-three of these were either pregnant or gave indisputable evidence of having recently born their young. The first specimen of this latter number was trapped February 27, the last April 20.

It would appear, then, that in this vicinity (Manhattan) the young are produced within a period of three to five weeks, mainly in March and early April. The period of gestation must be comparatively short, for signs of pregnancy did not appear until about five weeks before the first females gave evidence of having borne their young. My data on this point are not full enough to warrant a positive conclusion; for, of the twenty-five moles trapped during the months of December and January, and up to February 27, only five were females. This fact itself may be significant of a period of seclusion or less activity among the females during the period of pregnancy.

While, as stated above, the normal number of young is four, there were two cases in which there was but a single fœtus in one horn of the uterus; the other horn contained two, as usual. In one instance also there were five fœti.

That development after birth is very rapid is shown by the litter of young moles referred to in the last item in the accompanying table. These were discovered in a nest of dry grass under some sod, April 22. The sod had been turned over by the plow only about ten days previously. Although still perfectly hairless, these young moles weighed one ounce each—from one-fourth to one-third the weight of the adult.

Results of the Examination of 38 Female Moles for Breeding Conditions.

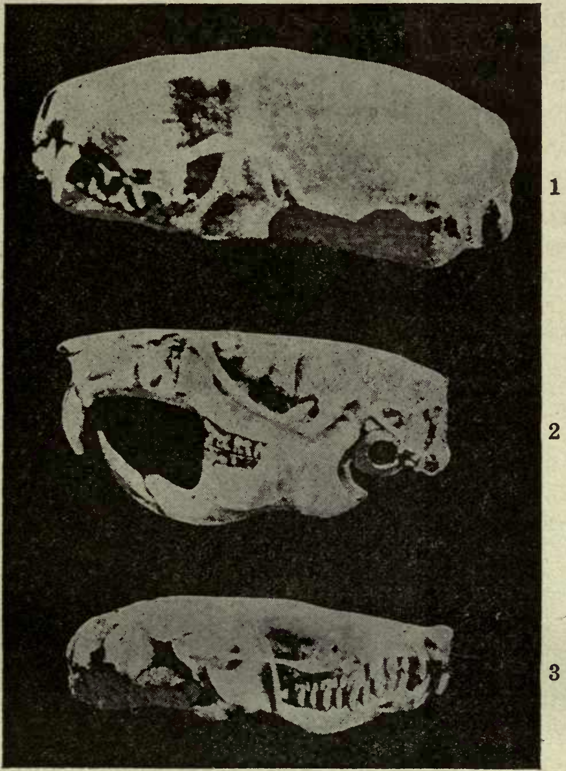
Date.	Conditions for breeding, number of embryos, etc.
Dec. 11,	No signs of pregnancy.
Dec. 17,	No signs of pregnancy.
Feb. 6,	No signs of pregnancy.
Feb. 20,	No signs of pregnancy.
Feb. 22,	No signs of pregnancy.
Feb. 27,	Uterus congested; very evidently pregnant.
Feb. 27,	Uterus very much congested, but fœti not distinguishable.
Feb. 27,	Uterus very much congested, but fœti not distinguishable.
Mar. 6,	Uterus very much congested, but fœti not distinguishable.
Mar. 7,	Three fœti in one horn of uterus, two in the other; scarcely distinguishable.
Mar. 8,	Pregnant. Number of fœti apparently four; scarcely distinguishable.
Mar. 8,	Two fœti in each horn of the uterus; very small.
Mar. 8,	Pregnant, but number of fœti not distinguishable.
Mar. 18,	Pregnant, but number of fœti not distinguishable.

Date.	Conditions for breeding, number of embryos, etc.
Mar. 22,	Pregnant, but number of fœti not distinguishable.
Mar. 26,	Pregnant, but number of fœti not distinguishable.
Mar. 29,	Pregnant, but number of fœti not distinguishable.
Mar. 30,	Two fœti in each horn of uterus; about as large as navy bean.
Mar. 30,	Two fœti in each horn of uterus; about as large as navy bean.
Apr. 1,	Two fœti in each horn of uterus; a little smaller than the above.
Apr. 2,	One fœtus in right horn of uterus, two in left; size of hulled peanut.
Apr. 8,	Indications that the young had been recently born.
Apr. 9,	Two fœti in each horn of uterus; size of navy bean.
Apr. 10,	Indications that young had been recently born; milk in glands.
Apr. 11,	Three fœti; size of small navy bean.
Apr. 13,	Four fœti, very small but easily distinguishable.
Apr. 13,	Young evidently recently born; uterus flabby and veins congested.
Apr. 14,	Young evidently recently born; number of fœti had been four.
Apr. 14,	Young evidently recently born; number of fœti had been four.
Apr. 14,	Young evidently recently born; number of fœti had been four.
Apr. 15,	Young born; evidences of being suckled.
Apr. 16,	Young evidently born.
Apr. 17,	Young born. Number of fœti had been four.
Apr. 17,	Young evidently born.
Apr. 19,	Young evidently born.
Apr. 20,	Young evidently born.
Apr. 20,	Young evidently born.
Apr. 22,	Four young moles taken in nest; weighed one ounce each.

SUMMARY.

Number of females pregnant or having recently borne young	33
Normal number of young, apparently	4
Largest number of young in any case	5
Smallest number of young in any case	3
Number of cases in which fœti were distinguishable	10
Cases in which condition of uterus indicated number of young recently born	4
Nests of young moles	1
Cases of 4 fœti	12
Cases of 3 fœti	2
Cases of 5 fœti	1

FOOD. The moles and the shrews constitute the sole representatives in North America of the mammalian order Insectivora (insect-eaters). A study of their dentition, the character of their food, and their general behavior in several respects, shows that they are much more closely related to the carnivorous or flesh-eating mammals than to the rodents, a group which includes the rats, mice, rabbits, squirrels and the like. This is especially true of the shrews, which are quite weasel-like in character. They fight savagely, kill and eat other small mammals larger than themselves, and when angry or excited emit a musky odor like the weasel and the mink.



Comparative dentition of a carnivore, a rodent, and a mole. (Adapted from D. G. Elliot.) 1—Skull of a weasel (*Putorius*). 2—Skull of a wood-rat (*Neotoma*). 3—Skull of a mole (*Scalops*).

It has long been known to scientists, through careful study and investigation, that the diet of moles consists mainly of the insects, grubs and worms to be found in the soil. This fact, however, has been slower in gaining popular credence than most scientific pronunciamentos. In another part of this bulletin the mole's guests have been called to account for the general prejudice which has arisen against him, and, again, in this connection, let it be understood that the mole is directly responsible for only a very small portion of any damage to seeds, grains and tubers in the ground. Field mice, voles and the common house mice are the guilty parties. If anyone is skeptical on this point he has only to set a few small mouse traps, properly baited, in the mole's runways and await results. In setting the trap a small excavation should be made with a knife or trowel. Place the trap on a level with the bottom of the runway. See that the latter is open both ways, and cover the excavation with a board or piece of sod to exclude the light and prevent the entrance of any small animal except by way of the burrow. Try various baits, such as soaked corn or peas, bits of meat, insects, and pieces of potato.

With respect to damage to roots and tubers by eating into them, it will usually be found on careful examination that the tooth marks are those of rodents.

Potatoes gnawed by rodents following in mole runways. Original.

EXAMINATION OF STOMACH CONTENT. Direct evidence of what an animal eats may usually be obtained in one or all of three ways: By examination of stomach contents, by observations in the field, and by experiments with captives. In the case of the mole field observations are of course impracticable. By the other two methods, therefore, we have endeavored to satisfy ourselves, and, we hope, others, as to the character of a mole's diet. The accompanying table gives the results of the careful examination of the stomach contents of 100 moles.

Results of Examination of 100 Moles' Stomachs.

Serial number.	Stomach Contents.
1	7 white grubs, 20 ants, 2 centipedes, 1 wasp.
2	2 white grubs, 1 earthworm, 1 beetle.
3	3 white grubs, 2 earthworms, 5 Diptera, beetle fragments.
4	8 white grubs, 3 larvæ (cutworms?), 1 beetle, plant rootlets.
5	2 white grubs, beetle fragments, 1 insect larva, plant fibers.
6	2 earthworms, 1 May beetle, 1 plant rootlet.
7	2 white grubs, 1 beetle larva, plant fibers.
8	5 white grubs, 5 beetle larvæ, 1 earthworm, 3 other larvæ, 1 cricket, fragments of vegetable tissue.
9	2 earthworms, 2 white grubs, 2 larvæ, 1 beetle, plant fibers.
10	15 white grubs (small), insect fragments.
11	5 earthworms, 1 white grub, 1 centipede, 1 fly, 1 cricket, 1 puparium, insect fragments.
12	2 earthworms, 18 ants, 1 beetle larva.
13	3 earthworms, 17 ants, 2 puparia, insect fragments, plant fibers.
14	2 white grubs, 2 beetles.
15	2 white grubs, 1 beetle larva, 2 beetles, 1 cricket, 1 ant, 3 centipedes.
16	2 earthworms, 3 insect cocoons, insect fragments.
17	8 earthworms, 19 white grubs, plant fibers.
18	1 earthworm, 1 puparium, 1 spider, 1 larva, plant fibers.
19	1 white grub, 1 earthworm, 1 centipede, 328 ants, 3 beetles, 1 tree cricket, plant fibers.
20	4 earthworms, 1 May beetle, 1 tiger beetle, 10 puparia, 2 beetle larvæ, 2 other larvæ.
21	1 beetle, 20 ants, 1 earthworm, insect fragments.
22	1 white grub, 3 cocoons, 6 larvæ, 1 beetle (Carabid), 1 beetle (Scarabid), plant fibers.
23	3 earthworms, 2 white grubs, 2 centipedes, 5 ants, 1 May beetle, 1 other beetle, 1 beetle larva.
24	1 earthworm, 1 centipede, 30 ants, 2 beetles, 1 beetle larva.
25	19 puparia, 1 earthworm, 16 ants, 1 beetle.
26	5 earthworms, 6 puparia, 2 beetles.
27	4 centipedes, 2 white grubs, 4 beetles, 5 beetle larvæ.
28	1 centipede, 2 beetle larvæ, insect fragments.
29	1 white grub, 2 ants, 1 beetle, insect fragments.
30	2 white grubs, 1 spider, 1 beetle, 1 May beetle, plant fibers.
31	1 beetle (Chrysomelid), 1 cocoon, 1 puparium, fragments of plant tissue.
32	1 white grub, 1 spider, 1 centipede, insect fragments, fragments of plant tissue.
33	1 May beetle, 1 ant, 1 beetle.
34	1 white grub, 82 ant puparia, 3 ants, 1 beetle, 1 beetle larva.
35	2 white grubs, 1 spider, 1 beetle larva, insect fragments.
36	1 white grub, 7 puparia, 1 centipede, 1 ant, 1 bug, 1 grasshopper, 1 May beetle, 1 tiger beetle.

Serial number.	STOMACH CONTENTS.
37	1 earthworm, 1 white grub.
38	1 beetle (Carabid), 2 white grubs, 2 larvæ, 1 beetle larva.
39	4 earthworms, 1 white grub, 10 cocoons, 1 centipede, 1 beetle (Carabid), 21 larvæ.
40	6 white grubs, 1 beetle, fragments of plant rootlets.
41	1 white grub, 1 cocoon.
42	2 beetle larvæ, 2 earthworms, several plant fibers and rootlets.
43	6 beetles, 3 beetle larvæ, 1 white grub, 1 spider.
44	1 beetle larva, 1 pupa, 1 white grub, 1 beetle, 1 earthworm.
45	4 earthworms.
46	3 earthworms, 15 small beetle larvæ, 1 white grub, 1 beetle, fragments of plant tissue.
47	1 white grub, insect fragments, 1 seed husk.
48	12 earthworms, 1 beetle larva, 2 white grubs.
49	4 white grubs, 2 earthworms, 1 ant, 1 bug, 1 cocoon, a few plant fibers.
50	3 white grubs, beetle fragments, a few bits of plant fiber.
51	4 earthworms, 1 white grub, 6 beetle larvæ, 1 wasp, fragments of plant tissue.
52	2 white grubs, 1 spider, 1 larva, insect fragments.
53	4 earthworms, 3 white grubs, 2 beetle larvæ, 1 cricket, 1 centipede, a few plant fibers.
54	5 white grubs, 1 earthworm, 15 beetle larvæ, 1 beetle, 1 cocoon of eggs, plant fibers.
55	6 earthworms, 7 white grubs, 2 beetle larvæ, 1 beetle.
56	6 white grubs, 1 earthworm, 1 beetle larva, insect fragments, fragments of plant tissue.
57	14 white grubs, 2 beetle larvæ, 2 beetles, 20 small larvæ.
58	2 white grubs, 2 wasps, 1 beetle, 1 beetle larva, insect fragments, 1 seed pod.
59	5 white grubs, 2 wireworms, 1 cricket, 1 wasp, 1 beetle, 3 beetle larvæ, 7 puparia.
60	4 white grubs, 2 earthworms, 1 beetle, 1 centipede, 1 spider.
61	12 white grubs, 2 earthworms, 2 beetle larvæ, 1 beetle, a few bits of plant tissue.
62	26 white grubs, 4 wireworms, 2 beetles, 1 centipede, 1 beetle larva.
63	2 puparia, 2 white grubs, 2 beetles, 3 centipedes, 2 beetle larvæ.
64	4 white grubs, 1 beetle, 1 beetle larva.
65	2 earthworms, 2 beetle larvæ, 1 beetle.
66	3 earthworms, 3 centipedes, 1 beetle, 1 puparium, 2 seed husks.
67	3 centipedes, 4 beetle larvæ, 2 beetles, 1 spider, 1 bit of plant tissue.
68	7 white grubs, 1 earthworm, 1 spider, 1 wasp, 1 beetle larva, 1 beetle, bits of plant tissue.
69	3 spiders, 1 beetle, 1 beetle larva, 1 plant rootlet.
70	171 small white grubs, 3 large white grubs, 1 May beetle, 1 beetle larva, 2 plant rootlets.
71	55 small white grubs, 1 grasshopper.

Serial number.	STOMACH CONTENTS.
72	Several spiders, 8 beetle larvæ, 1 earthworm, 1 wasp, fragments of several beetles.
73	3 beetles, 1 earthworm, 1 cocoon, 1 wasp, 3 beetle larvæ, skin of seed or root.
74	1 cocoon, 1 spider, 1 cricket, 1 earthworm, 1 beetle larva, 1 beetle, a few plant fibers.
75	4 earthworms, 8 puparia, 1 beetle, 1 cricket, 1 beetle larva, skin of seed or root.
76	1 earthworm, 1 spider, 1 May beetle, a few plant fibers.
77	1 earthworm, 7 beetle larvæ, 1 beetle, miscellaneous insect fragments.
78	3 beetles, 1 bug, 1 beetle larva, 1 white grub, insect fragments.
79	4 white grubs, 1 spider, 1 beetle, 2 beetle larvæ, a few plant fibers.
80	12 white grubs, 1 seed husk, a few plant rootlets.
81	44 insect larvæ, 1 beetle.
82	73 white grubs, 4 cutworms, 1 beetle, 1 larva, 1 seed husk, a few plant fibers.
83	1 earthworm, 2 spiders, 3 beetles, 1 cricket.
84	250 ant puparia, 2 beetle larvæ, 2 spiders, 2 beetles, a few plant rootlets.
85	3 earthworms, 1 spider, 8 puparia, 2 beetle larvæ, 1 beetle.
86	205 ants, 4 white grubs, 38 cutworms, 2 beetles, 1 spider, plant fibers.
87	2 earthworms, 1 puparium, 5 white grubs, 1 spider.
88	12 insect larvæ, 58 ants, 4 spiders, 1 hairworm (*Gordius*), 3 beetles.
89	3 cutworms, 60 ants, 1 beetle, 2 earthworms, skin of seed or root.
90	1 earthworm, 1 centipede, 18 puparia, 1 beetle.
91	10 cutworms, 1 spider, 1 beetle, insect fragments.
92	5 white grubs, 3 centipedes, 1 puparium, 1 cricket, 4 cutworms, a few plant fibers.
93	1 earthworm, 1 white grub, 3 larvæ, skin of seed or root, a few plant fibers.
94	2 centipedes, 5 cutworms, 1 spider, 2 larvæ, skin of seed or root.
95	2 centipedes, 1 puparium, comminuted mass of insect and centipede fragments.
96	3 white grubs, 1 larva, 1 centipede, 1 beetle, skin of grain or root.
97	4 white grubs, 1 cutworm, 1 ant, insect fragments, a few plant rootlets.
98	3 earthworms, 2 centipedes, 3 larvæ, 1 spider, 1 beetle, 1 puparium.
99	2 earthworms, 1 white grub, 2 centipedes, insect fragments.
100	1 white grub, 2 centipedes, 8 ants, mass of beetle fragments.

SUMMARY OF TABLE.

White grubs	64	stomachs
Earthworms	49	“
Beetles	67	“
Beetle larvæ	44	“
Other larvæ	25	“
Centipedes	25	“

Ants	19	stomachs
Wasps	7	"
Flies	2	"
Plant fibers and rootlets	43	"
Seed pods or husks	8	"
Crickets	10	"
Insect fragments	31	"
Puparia	21	"
Cocoons	10	"
Spiders	23	"
Grasshoppers	2	"
Bugs	3	"
Skin of grain or roots	6	"
Hair-worm	1	"
Number of stomachs infested by parasitic threadworms		28

In the course of the two years' investigations concerning the ways of the mole about 200 specimens have been checked up on our field notes. From this number the hundred individuals given above were selected so as to include some from each month of the year and to exclude any whose stomachs were empty or nearly so. The selections had no reference to stomach content, however, for they were made before examination of the latter.

The proportions of the various articles of food do not vary with the season as they do in the case of birds, for in some form the insects, worms and grubs listed in the above table are about as abundant in the soil at one time of the year as at another. It is scarcely necessary to add, however, that these supplies are not always equally accessible. In the summer when the soil is wet with recent rains the mole plows along very near the surface, extending his runways rapidly and gathering in a harvest of insects and worms, some of which have also come nearer the surface under these conditions. In dry periods or during portions of the winter season the mole must range deeper, for his prey has likewise found retreat farther down in the soil.

No attempt has been made to compute the actual percentages of each article of food in the list of twenty or more kinds given in the table. Such figures would be mere approximations at best. The end in view in the examination of each stomach was to discover what kind of creatures or substances it contained and, by noting repetition of similar parts of these organisms, how many of each kind.

While plant fibers or rootlets show up in forty-three cases, *in no case was the amount of identifiable plant tissue more than might have been taken in incidental to the ingestion of other food.* In many of the stomachs there was a considerable residue after repeated washings, filterings and eliminations of identifiable substances. This residue undoubtedly consisted largely of soil from the intestines of earthworms and finely comminuted animal and, perhaps, plant tissues. Even though starch, sugar or cellulose might be detected by chemical analysis, there would be no means of telling how much of this might have come from the digestive tracts of the insects taken as food.

Six stomachs contained fragments of plant tissue which may have been parts of the seed coat of corn, but resembled very closely thin bark from plant roots.

EXPERIMENTS WITH CAPTIVE MOLES. It is a difficult matter to keep a mole any considerable length of time in captivity. Altogether we have had more than a score under observation for a short time, but seldom have any of them been kept alive for more than a day or two. Either fright and worry, or lack of proper food in sufficient quantity, soon terminated the life of each captive. They have always been kept in tubs or boxes with a layer of earth several inches deep on the bottom. They were supplied with water and with food of several kinds, some of which they would eat readily. One individual survived for nearly two weeks and seemed to grow fat and sleek under the care we gave him. He finally died of too much kindness.

These imprisoned moles had insatiable appetites, eating ravenously bits of beefsteak and large numbers of earthworms. When freshly killed English sparrows were put in the cages in the evening, very little but bones and feathers would be left by morning. All refused to touch corn, potatoes or sweet potatoes, except the individual kept so long. He would eat these articles with some apparent relish, although he went about it very awkwardly. Instead of nibbling at a grain of corn as a rodent does, he would crowd it against the ground with his cheek and, gaining possession of it, chew it in the side of his mouth much as a steer chews a nubbin. The act or drinking water from a shallow dish was accomplished hog fashion, owing to the considerable projection of his snout beyond the aperture of the mouth.

When he was feeding on earthworms, there was no evidence of any attempt to first strip out the contents of the worm's alimentary canal, as has been reported by one investigator.

NATURAL ENEMIES AND CHECKS.

Birds. Probably no mammal on the North American continent has so few natural enemies as the common mole. Since it probably never leaves the darkness of its underground burrows except by accident, it is much less subject to attack by predatory animals than even the pocket gopher and the shrew, whose habits are somewhat similar to those of the mole. The following data gleaned from "Hawks and Owls of the United States," published by the United States Department of Agriculture, substantiates the above statement and shows how little the mole has to fear from the so-called birds of prey:

Birds.	No. of stomachs examined.	Remains of common moles.	Remains of shrews.	Remains of pocket gophers.
Red-tailed hawk (*Buteo borealis*)	562	6	46	8
Red-shouldered hawk (*Buteo lineatus*)	220	3	40	0
Broad-winged hawk (*Buteo latissimus*),	65	1	16	0
Barred owl (*Syrnium nebulosum*)	109	3	3	0
Barn owl (*Strix pratincola*)	39	0	5	8
Ten other hawks and owls (all that had eaten common moles, shrews, or pocket gophers)	1,131	0	35	14
Totals	....	13	145	30

In the above comparison it should be borne in mind that owls disgorge the pellets of bones and hair shortly after a meal. If to the figures on the pocket gopher in this table should be added the large numbers of those animals whose remains are found about the nests and roosting places of the barn owl and great horned owl, particularly, the total would be swelled enormously. Data on the number of moles and shrews found in similar situations are not at hand, but if their remains were at all conspicuous in the piles of disgorged pellets the matter would have received mention.

Mammals. The investigator has known personally of a few cases of keen-scented dogs acquiring the habit of searching out moles in fresh runways. The dog's sense of smell served to locate the mole, which was then pounced upon and speedily brought to the surface. In the files of the *Rural New Yorker* is found a short article by a subscriber in Missouri, who claimed to have several dogs that were adepts at this work.

These dogs, he states, were a cross between a Scotch collie and a prairie wolf, or coyote. This and other evidence at hand goes to show that the coyote, with his stealthy, skulking ways and his inquisitive nose, probably unearths many a luckless mole from the fancied security of his underground burrow. Judging from their general habits, it is probable also that foxes and badgers, and perhaps skunks, occasionally add moles to their bill of fare.

FLOODS. By far the greatest danger that manaces the adult mole and his progeny is the inundation of lowlands by heavy local rains or the waters of streams passing out of their banks. Such flooding of the soil is of comparatively frequent occurrence in the very situations where moles most abound, and probably serves more than all other things combined to check inordinate multiplication of the species. During the progress of the great June floods in 1903 and 1908, in the valleys of the Kansas and the Blue rivers, moles in large numbers could be found along the railroad embankments and in the driftwood that had lodged against the piers of bridges. What percentage of the adults perish under such conditions it is not possible to conjecture, but undoubtedly earlier spring freshets destroy most of the young on the flooded grounds. Certainly many of the adults survive these conditions, for they are good swimmers. On one occasion I captured more than a score in a single drift lodged against some piers. They seemed to be as vigorous and well fed as when taken under ordinary circumstances from surface burrows. This may be partly accounted for by the fact that the drift was full of beetles and other insects also seeking refuge from the water. Farmers and truck growers on the bottom lands have reported that after a flood subsides the moles and pocket gophers are not long in regaining their lost ground.

DAMAGE.

Considered from the standpoint of food habits alone, it has never been shown that the mole affects detrimentally the interests of the farmer and gardener. Indeed, it can be proven that quite the reverse is true. This statement will receive further consideration under the next heading. When, however, the mole is charged with disfiguring lawns and parks, destroying flower beds, tearing up the roots of grasses and making himself a general nuisance in small garden plots, he will have to plead guilty. The evidence against him is abundant and direct.

ECONOMIC STATUS.

In dealing with a mole it is all a question of whether or not that particular individual is out of place. The mole has his place among the forces of nature, and no unimportant role does he play. One of the most abundant of small mammals, his kind has for ages been working over the soil and subsoil in the interests of plant life. Within the limits of his normal range it is almost safe to say that every square yard of arable land is traversed one or more times each season by portions of his extensive runways. A part of this work is visible at the surface, but much of it is not. The hoe, the plow, the cultivator strike into unsuspected burrows everywhere. After a flood has subsided on lowlands the unequal settling at the surface of the ground discloses the fact that the soil is simply honeycombed with the runways of the mole and one or two other burrowing mammals. This tunneling and the shifting of earth particles permits better aeration of the soil and favors the entrance of water from the surface. It also mixes the soil and subsoil, carrying humus farther down and bringing the subsoil nearer the surface, where its elements of plant food may be made available by the agencies at work there. As an offset to this good work of the mole it may be urged that the earthworms, which form a large part of his diet, play a similar part in the economy of nature. This is true; but who knows but that the earthworm, which lives partly upon green vegetation, might become a terrible scourge if the mole were not placed as a check upon its increase. Nature preserves the balance of power very nicely in the animal world.

A large item in the stomach content of moles is made up of white grubs, those scourges of grass and other valuable plant roots. The table of stomach analyses (on pages 17-18) shows that nearly two-thirds of the moles had eaten white grubs. One had performed the astonishing feat of eating 175, another 73, and another 55. For his good work in destroying grubs alone, therefore, the mole deserves much credit. Among the beetles also, and the insect larvæ in general, which form a considerable part of the mole's food, are many forms that are injurious to agriculture. On the other hand, perhaps the bulk of the beetles were of those ground types that are predacious in habit and therefore may be considered either neutral or beneficial. It would be a tedious if not impossible undertaking to attempt to so classify these beetles as to determine the economic status of each individual or lot. In the vast majority of cases the fragmental character of the remains no more than served to distinguish the order. The spiders, centipedes and ants listed in the table may, as far as present knowledge goes, be reckoned as neutral or beneficial in their relation to agricultural interests.

The proportionately large amount of food consumed by a mole in a given time serves also to raise him in the rank of importance as a destroyer of noxious insects and their larvæ. A mole's appetite seems to be insatiable. Experiments with captives show that they will usually eat voraciously as long as they are supplied with food to their liking, often consuming more than their own weight in a day. This is not gluttony, as it is sometimes characterized. The tremendous amount of energy expended in plowing through the resistant soil requires a correspondingly large amount of food to supply that energy. That they must have this food at frequent intervals also is shown by the fact that a mole in captivity usually starves in a few hours unless supplied with nourishment.

The mole is one of nature's forces to be reckoned with by the agriculturist as he would reckon with nitrogen-forming bacteria, the birds that visit his fields and the bees that pollinate his fruit blossoms. If the individual mole is not out of place, mark him down as an asset and proceed accordingly. If he is where we do not want him, we are privileged to set swift death on his track in the form of traps, poison or club. For this reason—that a mole's presence in lawns, small garden plots, parks and cemeteries becomes intolerable—a line of experiments was undertaken to determine the better methods of getting rid of him in such situations. The results of these experiments follow.

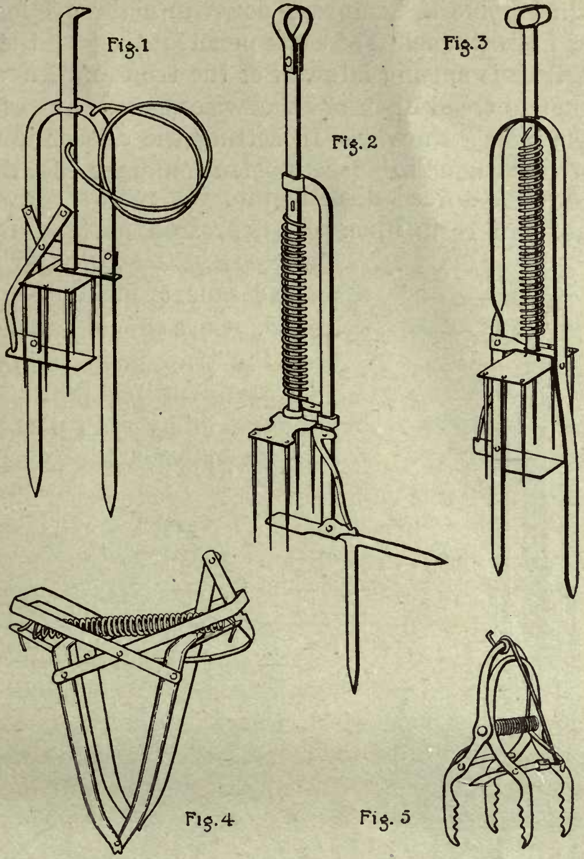
COMBATING THE MOLE.

The mole seems to possess a natural shrewdness and ability to sense danger out of accord with the life of seclusion which it leads. The common rat, from long association with man and hereditary knowledge of poisons and traps, has become proverbial for his sagacity and cunning, but the mole is almost his peer in these respects. This conclusion has been reached after dealing intimately with the mole for a period of two years. Like experience with the pocket gopher, an animal of somewhat similar habits, has demonstrated the fact that in this comparison he is stupidity itself, blundering into any sort of trap laid for him by the wiles of man.

TRAPPING. Trapping is the surest and, so far as my experience goes, the most practical method of getting rid of moles. I make this statement, however, without intention to disparage the utility of other methods. In some of the European countries villages and rural communities have their professional mole catchers, who follow the business for a livelihood. Correspondence with agricultural societies in two or three of these countries elicited the information that these professional catchers commonly use some sort of a trap which they construct themselves. These traps all have as part of their mechanism horse hair or fine wire loops which are drawn tightly about the body of the mole by the release of a pliant stick bent downward when the trigger is set.

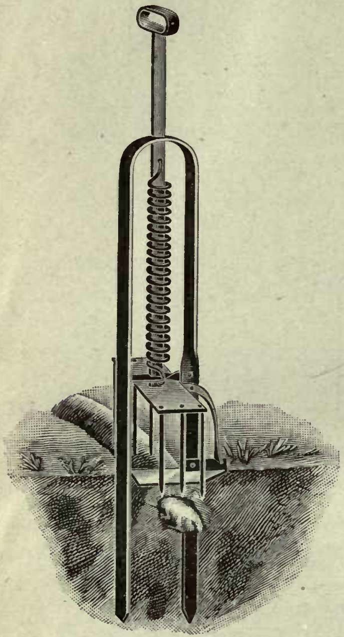
There are a number of excellent mole traps on the market in this country, any one of which, when properly handled, will give good results. All the different makes that have come under my notice depend upon the same sort of mechanism for releasing the spring; namely, a broad trigger-pan intended to be placed directly over a depressed spot in the mole's runway when setting the trap. The raising of this trigger-pan as the mole again upheaves the depressed portion of his surface burrow releases the contrivances designed to kill. The latter are of two types—sharp spikes which impale the mole when driven into the ground by the spring, or two pairs of scissor-like jaws which close firmly across the runway, one pair on either side of the trigger-pan. The arrangement of the spring, the safety catch and other details of individual trap construction are matters of secondary importance.

Plainly the efficiency of any animal trap depends upon its being so constructed as to adapt itself to the habits of the animal it is designed to capture. These mole traps conform to such requirements in at least two particulars—they can be set without exciting the animal's suspicions by entering or introducing anything into its burrow and are sprung by the mole in

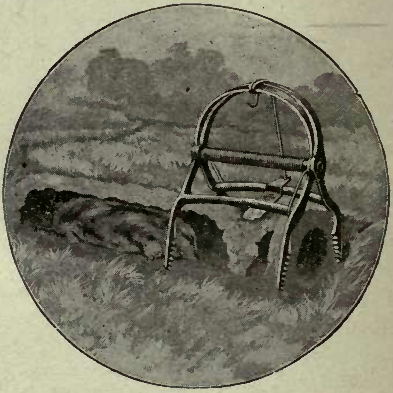


Types of mole traps. 1—The Side-spring trap. 2—The Wherry trap. 3—The Reddick trap. 4—The Chandler (Heartley) trap. 5—The Out o' Sight trap.

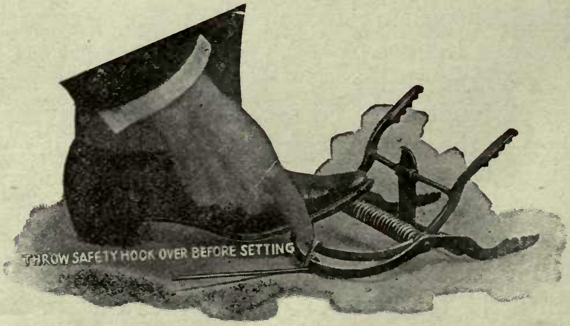
following its natural instinct to reopen its passageways when trodden down by passing feet or otherwise obstructed. Success or failure in the use of these devices depends largely upon the operator's knowledge of the mole's habits and of the machanism of his trap. To set a trap properly one should select a place in the surface runway where there is evidence of fresh work and with the toe of the boot firmly compress the ridge at one spot. If the trap is one of the harpoon or impaling types, raise the spring, set the safety catch and push the supporting spikes into the ground, one on either side of the runway, until the trigger-pan just touches the earth where it was trodden down. Now release the safety catch and allow the impaling spike to be forced down into the ground by the spring. This will facilitate their penetrating into the burrow when the trap is sprung later. Set the trap and leave it, taking care not to tread upon or otherwise disturb any other portion of the mole's runway. In setting the scissor-jawed trap known as the "Chandler" (see illustration, page 25), the points of the jaws are forced directly into the mole's runway until the trigger-pan rests upon the depressed portion as before, and the levers at the top are then pushed apart until the trap is locked. Care should be taken to see that the trap is in line with the mole's runway so that the little animal will have to pass through directly between the jaws. These



The Reddick set on a runway.



The Out o' Sight set on a runway.



Setting the Out o' Sight.

have already cut a path for themselves in the process of being spread apart. Another trap of this type, the "Out o' Sight" (see illustration, page 26), has a very strong spring and must be set by the aid of the foot while resting on a firm surface. It is then secured by a safety hook and its jaws forced into the ground, straddling the runway, until the trigger-pan touches as in the other traps. As the jaws of this trap are rather short it may be necessary sometimes to scrape off some of the grass and dirt on the top of the mole ridge in order to bring the trap down nearer to the actual burrow. Release the safety hook before leaving the trap.

It is useless to attempt the capture of moles by means of small steel traps or the ordinary snap mouse traps set in their runways. This fact became evident in trapping for mice and other guests of the mole. Scores of times the traps were carefully introduced into the burrows and the small excavation covered with sod so as to exclude all light. The results were always the same: scorning the bait or avoiding the unbaited trigger, the mole would plow his way beneath or to one side of the trap and pass on.

POISONING. There are a number of difficulties in the way of getting measurable results in experiments having to do with the poisoning of moles. The method used in conducting these experiments was as follows: A certain number of fresh runways—usually twenty-five—were selected and located by numbered stakes. Into each of these runways the poisoned bait was introduced at three to five different points through small openings made with a lead pencil or sharpened stick of about that size. These openings were then closed with a clod and the exact spot marked by a small pot label. After three or four days a careful inspection of all these locations was made to determine whether or not the bait had been taken or in any way disturbed. The runway was then opened up for a foot or two in each direction from the former location of the bait and left in this condition. In a few days another inspection of the runways was made to ascertain whether the moles were still at work, as would be evidenced by fresh ridging of the earth or by the filling up of that portion of the runway left open as stated above.

Now as to the interpretation of results: If the baits were taken wholly or in part there would be no means of telling whether they were eaten by the mole or by his guests, or even whether the mole had a chance to accept or refuse the bait before it was taken by other occupants of the burrow. The fact that a system of runways showed fresh work after poison had been introduced and the baits taken was, therefore, no evidence that the particular kind of bait was not suitable for the purpose. A mole's system of runways is so extensive that failure to retraverse or work that part of it under observation during the period of the experiment would not be positive evidence that the mole had been destroyed by the poison. Since there is so much intersection of burrows that it is difficult to determine the limits of each individual mole's system of runways, continued activity in the vicinity of a spot where poison had been put out would prove nothing more than that there was at least one mole alive there yet. The summary of more than a thousand records of poisoning operations show that but one dead mole was found.

In all poison experiments strychnia sulphate was used. Various baits were tried, with the following results and conclusions:

Peas. Peas were soaked for forty-eight hours in a solution of one-eighth ounce of strychnia in one quart of soft hot water. Seventy-eight per cent of the baits were taken, probably largely by mice, as sixty per cent of the runways continued to be worked by moles. This is undoubtedly an efficient bait for destroying the mice that follow the mole's runways in newly planted cornfields.

Fresh meat. Small bits of beefsteak were poisoned by inserting a crystal or two of strychnia into small slits made in the bait with the point of a penknife. About the same per cent of baits was taken as in the case of the peas, but a few of them were dug up from the surface. There is, therefore, danger of poisoning such keen-scented animals as dogs and cats by the use of these meat baits. Forty-two per cent of the runways treated showed fresh work after the close of the experiment.

Grasshoppers. The bodies of grasshoppers were poisoned in the same manner as the fresh-meat baits, the heads of the insects having first been pulled off. Sixty-one per cent of the baits were taken, but forty-four per cent of the runways continued to be worked.

Raisins. Raisins were poisoned by removing the seeds and inserting crystals of strychnia. About sixty per cent of these raisins were taken, but they proved to be the most efficient bait tried. Thirty-six per cent of the runways still showed fresh work, however. This bait is recommended by the department of botany of the Michigan State Agricultural College.

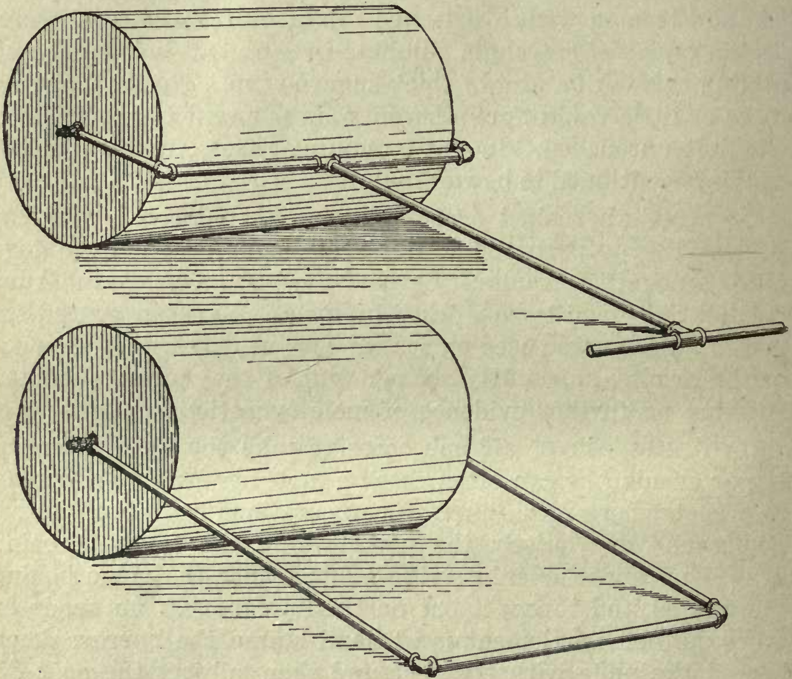
Green corn. Corn in the roasting-ear stage was cut from the cob and treated with a poisoned mixture prepared by dissolving an ounce of strychnia sulphate in a pint of hot water and mixing this with a pint of thick sugar syrup. This bait proved to be of little value, for in seventy-six per cent of the trials it was left untouched. In the remaining cases one-third of the runways continued to be worked.

Corn. Corn soaked over night and then treated with the poisoned syrup prepared at this Station for prairie dogs gave largely negative results. Seventy-five per cent of the runs treated continued to be worked by moles. Syrup prepared for pocket gophers was used on soaked corn as bait with somewhat better results, about fifty-six per cent of the runways treated showing no further evidence of mole operations.

CATCHING ALIVE. If one cares to take the time in morning or evening he can often catch a mole at work by watching in a spot where fresh burrowing operations have been noted. Approach very quietly the place where the earth is being heaved up and suddenly strike a spade into the ridge behind the animal and throw it out on the surface. If no spade or other suitable implement is at hand stamp the burrow down behind the mole with the foot and then subject the spot directly over the mole to like treatment or dig the animal out by hand.

When watering a lawn or irrigating a garden one can occasionally drive a mole to the surface by permitting a stream of water from hose or ditch to run into an open burrow for some time. This plan is not usually practicable, however, for it entails a waste of water, softens up spots in the lawn until they become boggy, and may result in flooding a cellar through an unsuspected runway following along the wall.

ROLLING THE LAWN. Repeated leveling of the mole ridges on a lawn by means of a suitable roller not only tends to discourage the animals from making any further inroads on the premises, but prevents that injury to the grass roots which would otherwise have resulted, and makes the lawn always appear sightly. A practical and substantial roller for this purpose may be made of cement, with gas-pipe axle and handles. It should weigh about 200 pounds.



Types of lawn rollers made of cement, with gas-pipe axle and frame. The form for setting the cement may be of wood, very narrow slats, or of galvanized iron. In the latter case the form may be left on the roller. The dimensions of the roller should be about 20 inches long by 14 inches in diameter.

TREATING SEED CORN TO PROTECT IT FROM BURROWING ANIMALS.

For several seasons the Station has been working on a line of experiments to determine means for preventing the theft of seed corn in the ground. A preliminary circular or bulletin on the subject was published a year ago, but at that time sufficient progress had not been made to warrant any final recommendations. Since the mole is very generally charged with these thefts, and since he is in reality accessory to the crime—by constructing highways which the real thieves follow—the results of this seed corn treating can be very properly given here.

These experiments have all followed one of three lines—baiting the pests some days in advance of planting, regular planting of poisoned seed, and surface coating of seed with ill-flavored substances.

Poisoned Bait. By baiting is meant the introduction of poisoned grain baits into the mole runways through small openings made with a stick. This puts the bait where it is sure to be found and minimizes the danger of its being taken by birds or any other animals than those for which it was intended. This plan also tends toward conserving the mole and destroying the mice, for the former is exceedingly suspicious of poisoned baits, while the latter will accept them readily. The sharp stick used for making the openings through the roof into the burrow should be no larger than one's finger. Close this opening with a clod after dropping in the kernels of poisoned grain. Corn, wheat or Kafir treated with the poisoned syrup prepared at the Station for destroying pocket gophers will make efficient baits. An excellent syrup for poisoning these grains may also be made as follows: Dissolve one ounce of strychnia sulphate in a pint of hot soft water. Add to this a pint of thick sugar syrup and mix the two by stirring. Pour enough of this syrup over the grain to thoroughly coat it. The one-quart mixture prepared as above should be sufficient for a half bushel of grain.

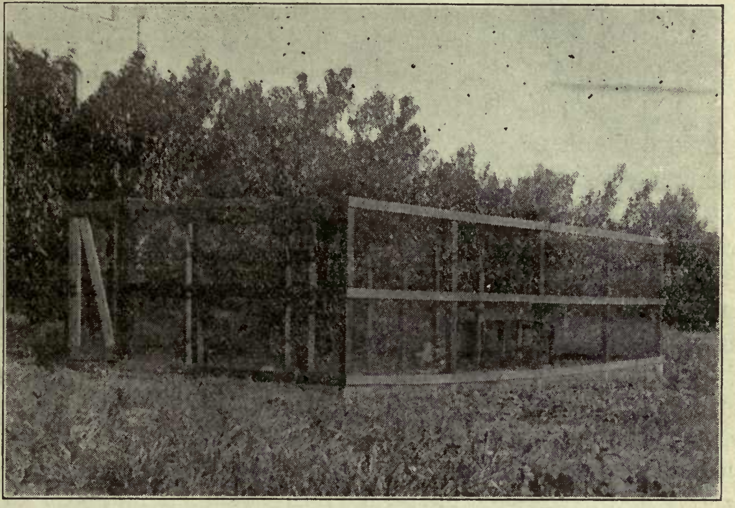
Poisoned Seed. An exhaustive series of tests has proven that seed corn intended for the regular planting may be poisoned without any resulting injury to its germinating qualities. For this poisoning, strychnia sulphate should be used.

As will be seen by reference to the table on page 35, both arsenic and corrosive sublimate seriously affect the viability of the seed. If the corn can be planted by hand it may be treated with either of the poisoned syrups referred to above. In garden plantings or along creek bends where the mole-mice pest is the most serious this method of planting can be followed to advantage. The seed corn may be allowed to dry after treating with the syrup, but if planted at once it should be handled with a spoon.

To poison seed corn so that it will still work in a planter, dissolve one ounce of strychnia sulphate in eight quarts of hot water, preferably rain water. In this solution, after cooling, soak one peck of seed for forty-eight hours, using as a container a vessel that will close tightly enough to prevent evaporation. When draining the corn at the end of the period of soaking save the poisoned water, as there will ordinarily be enough to soak a half peck more of seed. When corn so treated is thoroughly dried it will return to its former bulk, will have its germinating qualities unimpaired, and will work in a planter as well as untreated seed. Field experiments seem to indicate, however, that if heavy rains follow shortly after planting the poison tends to leach out of the grain. Under similar conditions the surface coating given by the poisoned syrup will also be partially washed off.

COATING SEED WITH OFFENSIVE SUBSTANCES. During the past two seasons an extensive series of tests has been made in treating seed corn with various ill-tasting substances calculated to deter burrowing animals from taking it. The results in most cases have been negative; that is, the seed was usually taken about as readily as though it had not been treated at all. In every case a counted number of kernels of treated corn were put out in not less than twenty different locations and the trial repeated at different seasons. All locations were accurately marked and carefully examined at regular intervals. The notes show that none of the substances used prevented the kernels of corn, or a portion of them, from being eaten or carried off. In most cases the corn was introduced directly into surface runways through an opening made by a lead pencil or small stick. Field plantings of treated corn were also made for two seasons on lands adjacent to small creeks. One of these plantings was entirely taken by fox squirrels as soon as the young plants began to show aboveground. A second planting was protected from a like fate by the use of traps and shotgun, and a fairly good stand of corn secured.

Experiments with about a dozen live spermophiles (striped ground squirrels) kept for months in the field cage shown in the illustration on this page demonstrated that these little animals will eat some of the corn, no matter how it has been previously treated. That, too, in spite of the fact that they were given untreated corn to eat during the progress of the experiments. When the freshly treated corn was exposed in saucers or trays they would generally eat the more palatable kinds first. When planted in plots and allowed to germinate or to grow to the height of an inch or two they would dig up all kinds indiscriminately.



The field cage for conducting experiments with captive mammals at the Kansas State Experiment Station.

The results of the tests of deterrent substances may be here briefly summarized:

SUBSTANCES WHICH HAVE BEEN FOUND TO INJURE THE GERM OF THE SEED. Kerosene, crude petroleum, copperas, crude carbolic acid, fish oil, spirits of camphor and turpentine, when used in sufficient quantity or strength to impart an odor to the corn, seriously injured the germinating powers of the grain. To treat the seed with any of these substances in such small quantity or dilute form as not to injure the germ is a waste of time, for the slight taste or odor imparted is soon dissipated by contact with the soil. Corn soaked in kerosene—an oft recommended treatment—for as short a time as five minutes, seriously impaired its germinating qualities.

SUBSTANCES NOT INJURIOUS TO THE SEED, BUT OF NO VALUE OR NOT AVAILABLE. Mixing pulverized gum camphor with the dry grain and storing in a closed vessel for some days has been recommended as an efficient treatment. The results were entirely negative. Little or no odor was imparted to the grain, and when the latter was placed in mole runways it was readily taken. Coating the corn with a thin paste of red lead and water has been recommended for protecting it against crows. When seed thus treated was placed in the spermophile cage, along with six other trays of corn that had been coated with deterrents, that subjected to the red lead treatment was the first to be eaten. Pine tar was used in some of the experiments. It has a strong odor but leaves the grain too sticky to work in a planter.

SUBSTANCES WHICH MAY BE USED WITH SOME DEGREE OF SUCCESS. Coal tar makes an ideal coating of a rich brown color and a persistent gassy smell. It dries nicely, is not in the least sticky when dried, and will therefore work well in a planter. Wet the grain with a little warm water before stirring in the tar. A tablespoonful of the latter will be sufficient for a peck of corn. The mass must be thoroughly mixed and then dried before attempting to plant. Mice show some aversion to corn thus treated, but ground squirrels do not seem to object to the coating. This deterrent is generally regarded as effective against crows, particularly by Eastern farmers. The Station has had no opportunity to test the matter. Soaking corn in strong tobacco decoction for twenty-four to forty-eight hours gives good results in some cases. Of course the grain must afterwards be thoroughly dried if it is to be planted by machine. It will still have a strong odor and will not be sticky. The decoction was prepared by steeping a pound of ordinary smoking tobacco in eight quarts of water. This will serve for soaking a peck of corn.

Treatment of Seed Corn with Deterrents and Poisons.
Germination Table.

(Average germination of the ten varieties of check or untreated corn in this test about 95 per cent.)

Substance used.	Treatment.	No. of grains tested.	Germination.
Kerosene	Corn surface-coated just before planting	600	74%
Coal tar	1 tablespoonful to peck. Planted at once	500	92
Coal tar	1 tablespoonful to peck. Dried before planting	1,100	95
Zenoleum	Corn surface-coated just before planting	400	93
Zenoleum	Corn surface-coated and dried before planting	1,000	93
Crow repellent	Corn surface-coated just before planting	200	94
Crow repellent	Corn surface-coated and dried before planting	800	94
Red lead	Corn surface-coated with paste in water	500	96
Tobacco	Decoction—1⅔ oz. to 1 qt. water. Soak 36 hrs.; dry	900	93
Gopher poison	Corn surface-coated just before planting	500	92
Gopher poison	Corn surface-coated and dried before planting	1,000	96
Strychnia sulphate	⅛ oz. to 1 qt. hot water; corn soaked 48 hrs.; dried	1,000	93
Water	Corn soaked 48 hrs.; dried before planting	1,000	93
Arsenic	Corn wet in very dilute mucilage; powdered with arsenic	100	82
Corrosive sublimate	Corn soaked in 1% solution for 1 hr.; dried	50	14
Spirits of camphor	Corn soaked in spirits for 24 hrs.; dried	100	00
Pine tar	Corn surface-coated; dried before planting	100	92
Crude petroleum	Corn surface-coated just before planting	100	18
Fish oil	Corn surface-coated just before planting	100	54
Crude carbolic acid	Corn surface-coated just before planting	100	44
Copperas	1 oz. to one gallon of water; corn soaked 24 hrs.; dried	100	79

MOLES FOLLOWING THE LISTER FURROW. In connection with the report on treating seed corn it may be well to give here the results of some observations on the mole's alleged habit of following in the bottom of the listed furrow. There is no doubt but that the little animal is guilty, as charged, of following a course by preference along the straight trail of freshly loosened earth made by the drill-shoe. That he is seeking out the seed corn is only a matter of inference from his following the furrow. The truth of the matter is that it is probably the white grub that attracts him, not the corn. The presence of moles in rich lawns, garden plots and along creeks in cornfields is a symptom, not a disease. The white grub is the disease. The record of accurate observations on a twenty-acre cornfield in Illinois shows an average of over thirty-four grubs to the square yard. It is needless to say that this field produced but little corn. The grub eats the young corn shoots before they are up and attacks the root system at any time throughout the season.

The following table gives the results of careful measurements and counts made day by day on twenty rows of corn in rich ground along a little creek. The data given are calculated to show to what extent the mole traverses or crosses the lister furrow:

PLANTING "A."					PLANTING "B."				
Row.	Greatest number of places traversed by runs at one time....	Greatest total length of runs in furrow at any one time......	Greatest number of times run merely crossed the furrow..	Total length of row...	Row.	Greatest number of places traversed by runs at one time....	Greatest total length of runs in furrow at any one time......	Greatest number of times run merely crossed the furrow..	Total length of row...
		feet.		*feet.*			*feet.*		*feet.*
1........	9	159	3	825	1.......	6	170	8	825
2........	11	59	8	825	2.......	11	93	5	825
3........	10	75	10	825	3.......	13	459	4	825
4........	8	41	6	825	4.......	14	246	4	825
5........	10	34	8	756	5.......	11	107	3	756
6........	4	19	13	756	6.......	9	157	2	756
7........	5	62	6	696	7.......	6	56	3	696
8........	4	20	9	354	8.......	5	69	4	354
9........	3	29	6	354	9.......	7	178	2	354
10........	3	38	4	354	10.......	6	70	5	354

The above figures give the greatest totals noted at any one time. After heavy rains counts and measurements would differ from these figures. Probably nearly the entire lengths of the rows were traversed at different times. The injurious effect of the mole's running under the young corn shoots was most noticeable in the dry periods. However, the number of shoots of corn known to have died from having their roots heaved up totaled but 53.

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